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ROCKWELL INTERNATIONAL
NORTH AMERICAN SPACE OPERATIONS
ROCKY FLATS PLANT

Feasibility Study Report for High Priority Sites

(881 Hillside Area)

Volume I

U.S. DEPARTMENT OF ENERGY

Rocky Flats Plant
Golden, Colorado

1 MARCH 1988

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By R. B. Hoffman
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APPROVALS

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March 2, 1988

88-RF-0623

Albert E. Whiteman
Area Manager
DOE, RFAO

FEASIBILITY STUDY REPORT FOR
HIGH PRIORITY SITES (881 HILLSIDE AREA)

Enclosed are two (2) copies of the Feasibility Study Report for the High Priority Sites (881 Hillside Area) and a preliminary schedule for implementation of the recommended remedial action. This report and preliminary schedule were submitted to CDH and EPA by March 1, 1988 in accordance with Task 3.10 of the Feasibility Study Report including Risk Assessment as required by the Compliance Agreement The report will be finalized pending CDH, EPA and public review and comment as part of the RI/FS process.

If you have any questions concerning the report, please call T. C. Greengard at extension 7121.

Keith McKinley

K. B. McKinley
RCRA/CERCLA Program

Enc. 2

Orig & 2 cc - A. E. Whiteman

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1.0 INTRODUCTION

1.1 SITE BACKGROUND INFORMATION

1.1.1 Overview

A comprehensive, phased program of site characterization, remedial investigations, feasibility studies, and remedial/corrective actions is in progress at the Rocky Flats Plant. These investigations are pursuant to the U.S. Department of Energy (DOE) Comprehensive Environmental Assessment and Response Program (CEARP) and a Compliance Agreement between of DOE, the U.S. Environmental Protection Agency (EPA) and the State of Colorado (CDH) dated July 31, 1986. The Agreement addresses hazardous and radioactive mixed waste management at the Rocky Flats Plant.

CEARP is being implemented in five phases which include all elements of the Remedial Investigation/Feasibility Study (RI/FS) process. CEARP Phase 1 (Installation Assessment) has already been completed at Rocky Flats Plant. CEARP Phase 1 evaluated the magnitude of potential environmental concerns. CEARP Phase 2 (Monitoring Plans and Remedial Investigations) will complete the environmental evaluation and will plan and carry out sampling programs to delineate potential contaminant sources, environmental pathways, and the extent and nature of contamination. CEARP Phase 3 (Feasibility Studies) will develop remedial action plans to mitigate environmental problems identified as needing correction in CEARP Phase 2. CEARP Phase 4 (Remedial/Corrective Action) will implement recommended site-specific remedial actions identified in CEARP Phase 3. CEARP Phase 5 (Compliance and Verification) will verify and document the adequacy of remedial actions carried out under CEARP Phase 4 and identify and plan for any continuing monitoring requirements.

CEARP Phase 2 consists of CEARP Phase 2a, Monitoring Plans, and CEARP Phase 2b, Remedial Investigations. CEARP uses a three-tiered approach in preparing monitoring plans: the CEARP Generic Monitoring Plan (DOE, 1986a), the Installation Generic Monitoring Plan/Comprehensive Source and Plume Characterization Plan (DOE, 1987a), and the Site Specific Monitoring Plans (SSMPs). A site specific monitoring plan for the 881 Hillside was submitted to EPA and CDH in February 1987 (DOE, 1987b). The plan serves as the Work Plan for Performance of Remedial Investigations and Feasibility Studies for High-Priority Sites at the Rocky Flats Plant. The Monitoring Plan consists of six parts: Synopsis, Sampling Plan, Technical Data Management Plan, Health and Safety Plan, Quality Assurance/Quality Control Plan, and the Feasibility Study Plan.

A remedial investigation report for the high priority sites at Rocky Flats was submitted to EPA and the Colorado Department of Health (CDH) on July 1, 1987, in accordance with the schedule set forth in the Compliance Agreement. Results of additional drilling and responses to EPA and CDH comments on the July report have been incorporated into the final draft remedial investigation report, submitted to the EPA and the CDH on March 1, 1988. The report provides verification of the existence and location of the high priority waste disposal sites, a characterization of the sites, and an evaluation of the nature and extent of contamination.

This report describes the results of the feasibility study of the high priority sites at Rocky Flats Plant. The feasibility study proposes and assesses alternative remedial actions that eliminate or control environmental contamination at the high priority sites. The assessment considers the following elements:

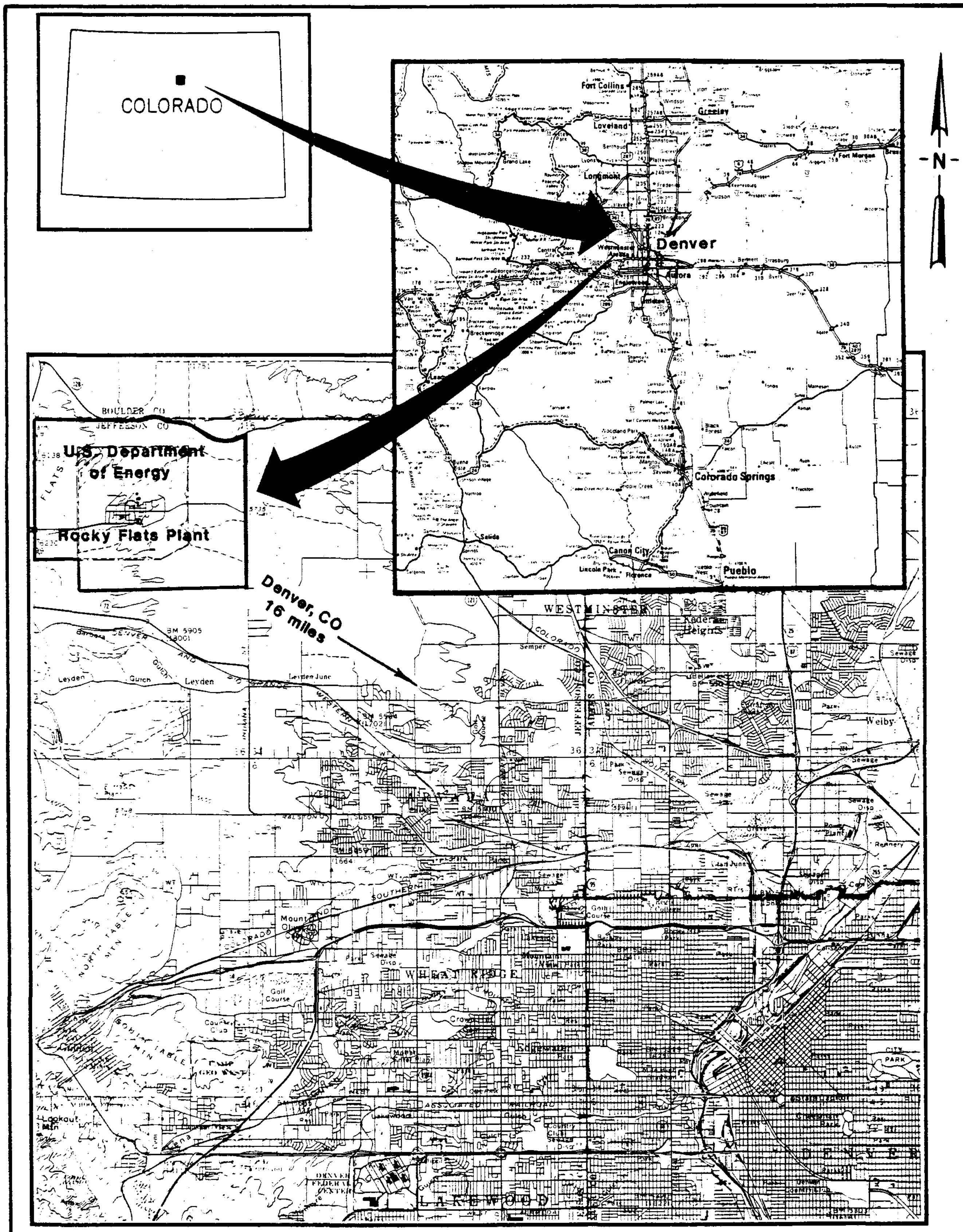
- a technical analysis of the alternative approaches in terms of performance, reliability, ease of implementation, and safety;
- an institutional analysis of the alternative remedial actions in terms of federal, state, or local standards, advisories, or guidelines that must be attained or considered to protect public health and welfare, and the environment;
- an evaluation of public health exposure (see Appendix 1: Risk Assessment);
- an environmental analysis of alternative remedial actions; and
- a cost analysis of alternative remedial actions.

1.1.2 Site Description and Location

1.1.2.1 Rocky Flats Plant

The Rocky Flats Plant is located in northern Jefferson County, Colorado, approximately 16 miles northwest of downtown Denver (Figure 1-1). The site consists of approximately 6550 acres of federally owned land in Sections 1 through 4 and 9 through 15 of T2S, R70W, 6th principal meridian. Major buildings are located within an area of approximately 400 acres, known as the Plant security area. The security area is surrounded by a buffer zone of approximately 6,150 acres.

The Rocky Flats Plant is a government-owned, contractor-operated (GOCO) facility. It is part of a nation-wide nuclear weapons research, development, and production complex administered by the Albuquerque Operations Office of the U.S. Department of Energy. The operating contractor for the Rocky Flats Plant is Rockwell International.



Not To Scale

Figure 1-1 : Location of Rocky Flats Plant

The facility manufactures components for nuclear weapons and has been in operation since 1951. The Plant fabricates components from plutonium, uranium, beryllium, and stainless steel. Production activities include metal fabrication, machining and assembly. Both radioactive and nonradioactive wastes are generated in the process. Current waste handling practices involve on-site and off-site recycling of hazardous materials and off-site disposal of solid radioactive materials at another DOE facility. In the past, both storage and disposal of hazardous and radioactive wastes occurred at on-site locations. Preliminary assessments under CEARP Phase 1 identified some of the past on-site storage and disposal locations as potential sources of environmental contamination.

1.1.2.2 Demography

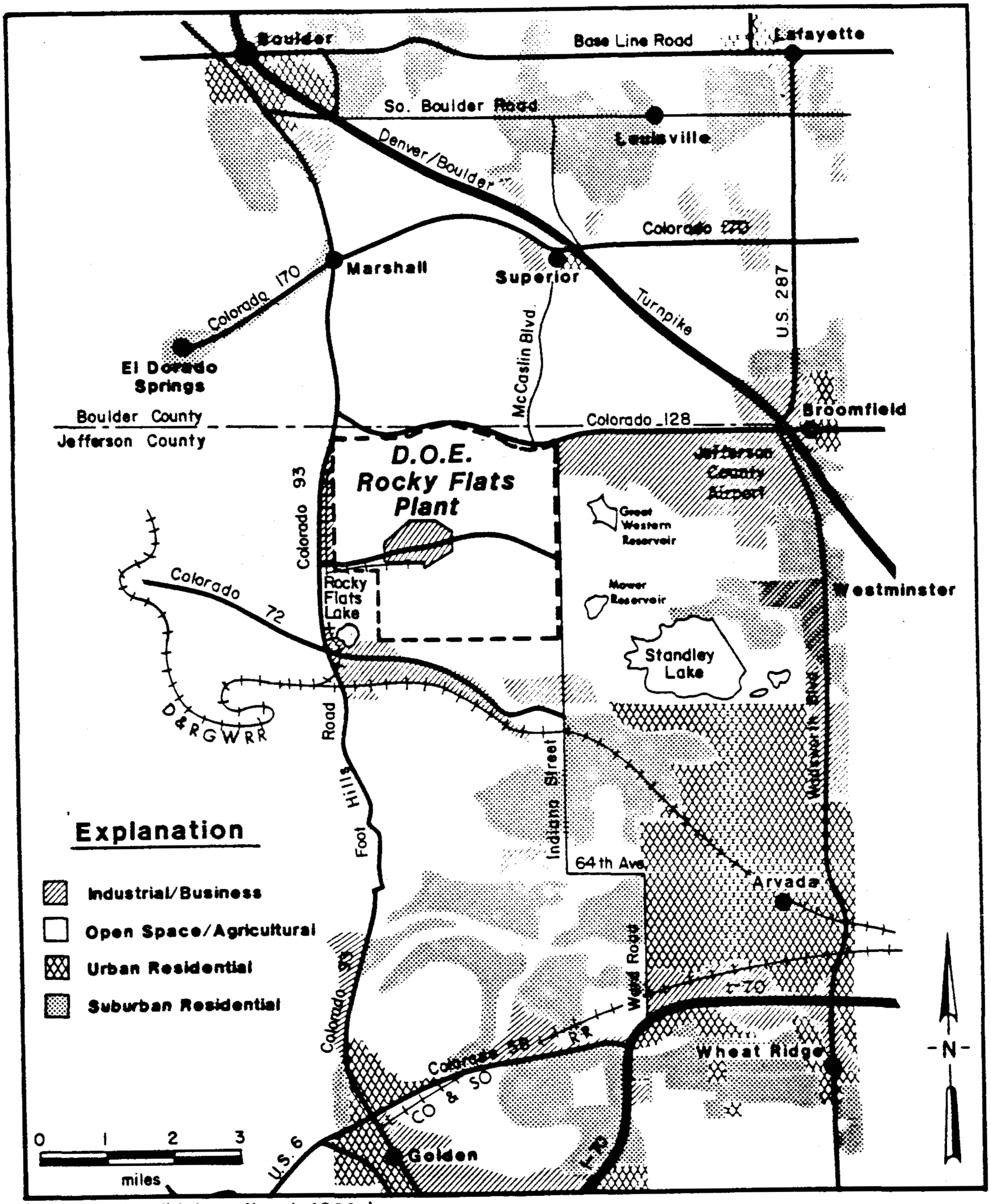
Approximately 50 percent of the area within 10 miles of the Plant is in Jefferson County. The remainder is located in Boulder County (40 percent) and Adams County (10 percent). According to the 1973 Colorado Land Use Map, 75 percent of this land was unused or was used for agriculture. Since that time, portions of this land have been converted to housing, with several new housing subdivisions being started within a few miles of the buffer zone. One such subdivision is located south of the Jefferson County Airport and several are located southeast of the Plant.

A demographic study using 1980 census data (Setlock and Barker, 1985) shows that approximately 1.8 million people lived within 50 miles of the Plant in 1980. This was projected to increase to 3.5 million people by the year 2000. Approximately 9,500 people lived within 5 miles of the Plant in 1980, with a projected increase to 20,000 people by the year 2000. The most populous sector was to the southeast, toward the center of Denver. This sector had a 1980 population of about 555,000 people living between 10 and 50 miles from the Plant, with a projected increase to 1.5 million by the year 2000.

1.1.2.3 Land Use

The Rocky Flats Plant is located in a basically rural area (Figure 1-2). There are no public facilities or institutions such as schools, prisons, or hospitals within five miles of the Plant. The nearest educational facility is the Sierra Elementary School, which is six miles southeast of the Plant. Other schools are located in the same general area, but somewhat farther from the Plant. The closest hospital to the Plant is Boulder Memorial Hospital, 10 miles northwest. The closest park and recreational area is the Standley Lake area, which is approximately 5 miles from the Plant site. Boating, picnicking, and limited overnight camping are permitted. Several other small parks exist in communities within 10 miles of the Plant. The closest major park, Golden Gate Canyon State Park, located approximately 15 miles to the southwest, provides 8,400 acres of general camping and outdoor recreation. Other national and state parks are located in the mountains west of the Plant, but all are more than fifteen miles away.

Some of the land adjacent to the Plant is zoned for industrial development. Industrial facilities within 5 miles of the Plant include the TOSCO laboratory (40 acre site located 2 miles south), the Great Western Inorganics plant (2 miles south), the Frontier Forest Products yard (2 miles south), the Idealite lightweight aggregate plant (2.4 miles northwest), and the Jeffco Airport and Industrial Park (990 acre site located 4.8 miles northeast).



(after: Rockwell International, 1986a)

Figure 1-2

Land Use in the Vicinity of Rocky Flats Plant

Several ranches are located within 10 miles of the Plant, primarily in Jefferson and Boulder Counties. They are operated to produce crops, raise beef cattle, supply milk, and breed and train horses. According to the 1977 Colorado Agricultural Statistics, 14,000 acres of crops were planted in 1976 in Jefferson County (total land area of approximately 475,000 acres) and 56,200 acres of crops were planted in Boulder County (total land area of 405,760 acres). Crops consisted of winter wheat, corn, barley, dry beans, sugar beets, hay, and oats. Livestock consisted of 9,500 head of cattle, 200 pigs, and 400 sheep in Jefferson County and 34,000 head of cattle, 2,300 pigs, and 6,500 sheep in Boulder County.

1.1.2.4 High Priority Sites

CEARP Phase 1 Installation Assessment for Rocky Flats Plant included analyses of current operational activities, active and inactive waste sites, current and past waste management practices, and potential environmental pathways through which contaminants could be transported. CEARP Phase 1 identified approximately 70 sites or groupings of sites that could potentially have adverse impacts on the environment. Data collected during preparation of the RCRA Part B Operating Permit Application identified several additional potential sites. All of these potential sites at Rocky Flats Plant were designated as solid waste management units (SWMUs), and assigned a reference number.

Hydrogeological and hydrogeochemical characterization on an installation-wide basis was performed at Rocky Flats in 1986 as part of the preparation of the Plant RCRA Part B Permit Application. Analysis of these data has identified four areas which are the most probable sources of environmental contamination, with each area containing several sites. These areas are the 881 Hillside Area, the 903 Pad Area, the

Mound Area, and the East Trenches Area. The twelve sites (SWMUs) comprising the 881 Hillside Area were investigated as the high priority sites because of elevated concentrations of volatile organic compounds in the ground water and proximity of the sites to a surface drainage. As shown in Figure 1-3, the 881 Hillside Area is located at the southeast corner of the plant.

The 881 Hillside Area has been the site of various spills and disposal operations during the history of the plant. The twelve SWMUs that make up the 881 Hillside Area are described below (see Plate 1-4 for locations).

- Oil Sludge Pit (SWMU Ref. No. 102) - Approximately 30 to 50 drums of oil sludge were emptied into a pit south of Building 881 in the mid-1950s. The sludge was collected during cleaning of the two No. 6 fuel oil tanks south of Building 881 (SWMUs 105.1 and 105.2). The pit was located approximately 180 feet south of the southeast corner of Building 881 and had dimensions approximately 50 by 80 feet (Rockwell International, 1986a). The oil sludge pit site was identified on 1955 aerial photographs and was covered with fill after its use based on 1963 aerial photographs.

- Chemical Burial Site (SWMU Ref. No. 103) - An area south of Building 881 was reportedly used to bury unknown chemicals (DOE, 1986b). The exact location, dates of use, and contents of the site are unknown. Prior to this investigation, the site was thought to be located in the same area as the Oil Sludge Pit Site (Rockwell International, 1986a). The location of this unit has been revised based on this investigation (Section 4.0).

- Liquid Dumping Site (SWMU Ref. No. 104) - An area east of Building 881 was reportedly used for dumping unknown liquids and for disposing of empty drums prior to 1969 (DOE, 1986b). A pit was reported with plan dimensions of approximately 50 by 50 feet based on 1965 aerial photographs (Rockwell International, 1986a). Further analysis of the air photos during this investigation did not confirm the preliminary identification made in 1986 (Section 4.0).

- Out-of-Service Fuel Tank Sites (SWMU Ref. No. 105.1 and 105.2) - Asbestos was placed in two out-of-service no. 6 fuel tanks located south of Building 881, and the tanks were later filled with concrete (DOE, 1986b). The exact dates of these activities are unknown; however, they apparently occurred subsequent to use of the fuel oil storage tanks (after 1976) (Rockwell International, 1986a).

- Outfall Site (SWMU Ref. No. 106) - A six-inch diameter vitrified clay pipe outfall existed south of Building 881. This pipe discharged water in 1977. Previous reports indicated that this was a cleanout pipe for an overflow line from the Building 881 cooling tower (Rockwell International, 1986a). However, construction drawings reviewed during this investigation indicate that the pipe is an overflow sewer line from Building 887 (Section 4.0).

- Hillside Oil Leak Site (SWMU Ref. No. 107) - An oil leak was discovered on the hillside south of Building 881 in May 1973. The oil was believed to be from the fuel oil storage tanks south of Building 881 (SWMUs 105.1 and 105.2); however, leak tests on the tanks and associated lines did not show any leakage. The oil spill was contained with straw, and the straw and soil were removed and disposed of in the present landfill north of the Plant (Rockwell International, 1986a).

  Prior to 1975, oil had emerged through the Building 881 footing drain outfall. A ditch and skimmer pond were built to contain the oil. These structures are still present, although no oil has been observed in the outfall since 1973 (Rockwell International, 1986a). SWMU 107 includes the Building 881 footing drain and skimmer pond.

- Multiple Solvent Spills Sites (SWMU Ref. No. 119.1 and 119.2) - Beginning in 1967, two areas east of Building 881 and along the southern perimeter road were used as solvent storage facilities. The two areas were expanded from 1967 to 1971, and major expansion of the western area (SWMU 119.1) occurred in 1969. Both storage facilities were removed by 1972. The exact types and quantities of solvents stored at this facility are unknown (Rockwell International, 1986a).

- Radioactive Site - 800 Area Site #1 (SWMU Ref. No. 130) - An area east of Building 881 and northwest of SWMU 119.1 was used from 1969 to 1972 to dispose of up to 400 tons of plutonium contaminated soil. These materials were derived from cleanup of the area around Building 776 after the 1969 fire and from Central Avenue between 8th and 10th Streets. The average plutonium activity of the material from the fire cleanup was estimated to be seven disintegrations per minute per gram (dpm/g) (Rockwell International, 1986a).

- Sanitary Waste Line Leak (SWMU Ref. No. 145) - A four-inch cement-asbestos sanitary waste line located south of Building 881 leaked in January 1981. An earthen dike was constructed to prevent the spill from entering the South Interceptor Ditch, and the line was repaired. The presence of hazardous materials in this line is unknown (Rockwell International, 1986a). Review of Building 881 construction drawings does not indicate any four-inch cement-asbestos sanitary waste lines south of the building.

- Building 885 Drum Storage Area (SWMU Ref. No. 177) - The Building 885 Drum Storage Area will be closed under RCRA Interim Status (6

CCR 1007-3). Complete information on this unit is provided in the RCRA Closure Plan.

1.1.3 Geology

1.1.3.1 General Vicinity

The Rocky Flats Plant is located at an elevation of approximately 6,000 feet above mean sea level. The site is on the western margin of the Colorado Piedmont section of the Great Plains Physiographic Province (Fenneman, 1931). The piedmont represents an old erosional surface along the eastern margin of the Rocky Mountains. It is underlain by gently dipping sedimentary rocks (Paleozoic to Cenozoic in age), which are abruptly upturned at the Front Range (just west of the Plant) to form hogback ridges parallel to the mountain front. The piedmont surface is broadly rolling and slopes gently to the east with a topographic relief of only several hundred feet. This relief is due both to resistant bedrock units that locally rise above the surrounding landscape and to the presence of incised stream valleys.

The general geologic structure of the area is north-striking beds with dips to the east. Dips are quite steep west of the Plant, on the order of 50 degrees or greater. However, because the axis of the monocline onto the Front Range appears to be inclined to the east, dips become rapidly more gentle, on the order of 7 to 15 degrees beneath the Plant itself.

The stratigraphic section in the vicinity of the Plant begins with the Fountain Formation (Figure 1-5), unconformably overlying the Precambrian metamorphics and steeply dipping to the east. The Fountain is overlain by various units, including the thick and relatively impermeable Upper Laramie Formation. Because of the thickness

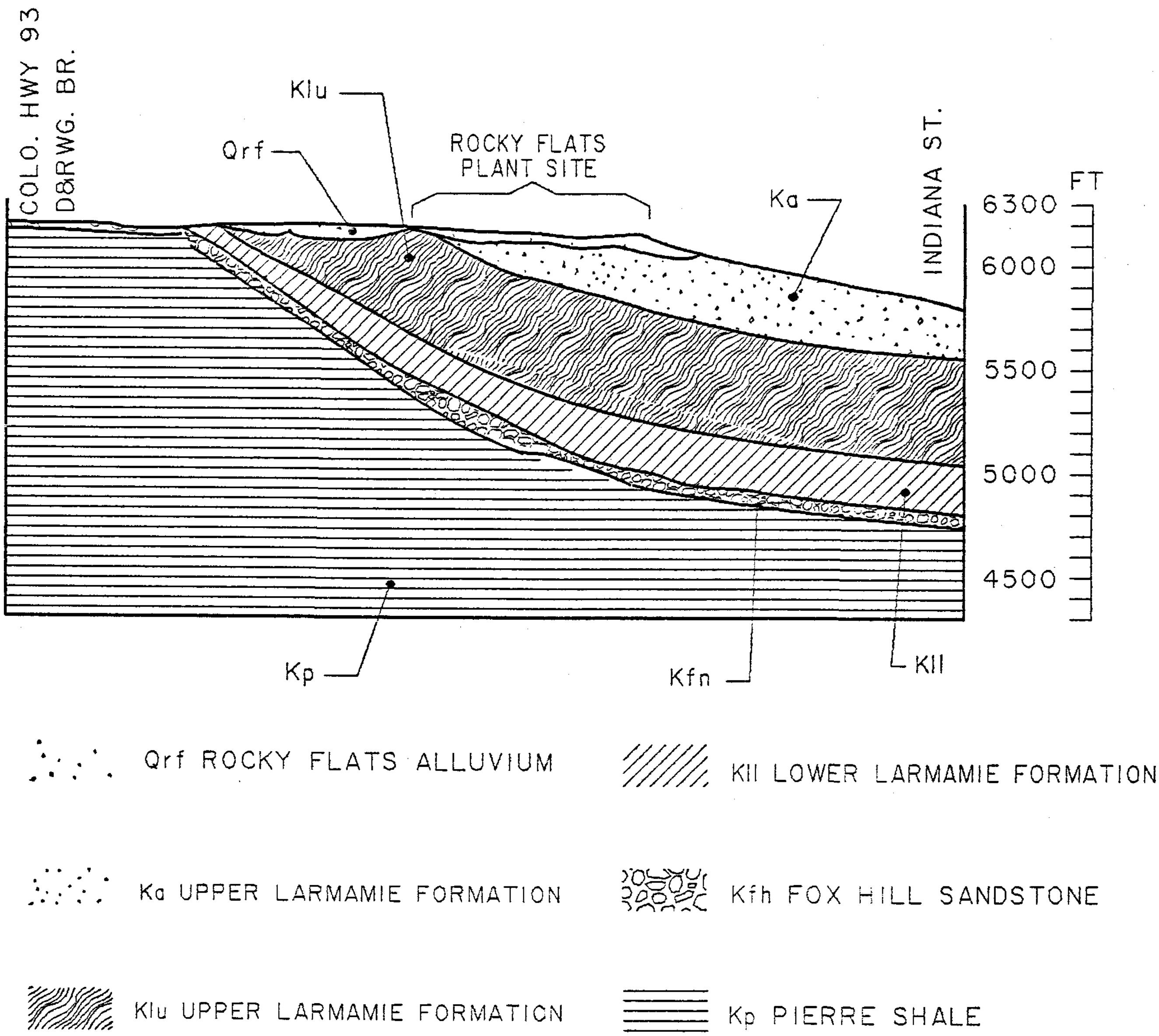


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Fig. 1-5:
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(750 to 800 feet) and low permeability of the Upper Laramie, it is considered to be the base of the hydrologic system which could be affected by Plant operations.

Upper Laramie Formation

The Upper Laramie is approximately 750 to 800 feet thick and consists of buff to dark-gray, organic-rich claystone. In many localities there are interbedded sand layers near the base (Hurr, 1976).

Arapahoe Formation

The Arapahoe is a continental deposit of lenticular sand bodies interbedded with clay. Carbonaceous remains of plant material are commonly found where sand and clay are thinly interbedded. The lower half of the formation contains more sand beds than the upper half. The thickness of the Arapahoe has been reduced beneath the Plant by erosion before deposition of the Rocky Flats Alluvium, and is generally less than 270 feet. The thickness of the Arapahoe elsewhere in the basin where overlain by the Denver Formation ranges from 270 to 445 feet.

Sand bodies in the Arapahoe rarely exceed 5 to 8 feet thick. The lateral extent of the sands may be hundreds of feet, but tens of feet are more common. In many localities, the same stratigraphic horizon contains several sand bodies which are not laterally connected (Hurr, 1976).

Rocky Flats Alluvium

The Rocky Flats Alluvium unconformably overlies the Laramie and Arapahoe Formations in the vicinity of the Plant. The deposit is a series of laterally coalescing alluvial fans deposited by streams (Hurr, 1976). The fans were deposited on an erosional surface cut into the bedrock units that has 50 feet of relief or more, including channelization around the hogbacks of the Lower Laramie. The alluvium consists of beds of clayey, sandy silt, some of which contain distinct horizons of subrounded gravel and cobbles. Locally, there are lenses of clean, moderately sorted medium to very coarse sand. The clayey, sandy silt is yellowish to light-reddish brown which gives the formation its characteristic color. Locally, calcium carbonate enrichment mottles the soil texture between 1 to 5 feet below land surface. The alluvium (generally 10 to 50 feet thick, although the alluvium is as much as 100 feet thick west of the Plant) has been eroded by Walnut Creek on the north and Woman Creek on the south so that bluffs along these streams range in height from 50 to 150 feet. The gradient of the gently eastward-sloping, dissected Rocky Flats Alluvium surface varies from 0.7 percent at the Plant to approximately 2 percent just east of the Plant.

1.1.3.2 881 Hillside Area

The 881 Hillside is located on the southern flank of the Plant on a slope from the Rocky Flats surface down to Woman Creek. The following geologic information is based on the Remedial Investigation Report for High Priority Sites (881 Hillside Area) (Rockwell International, 1988), and the reader is referred to this report for additional details. Plate 1 identifies the boreholes and wells referenced in this section.

Surficial Materials

Surficial materials at the 881 Hillside Area consist of the Rocky Flats Alluvium, colluvium, valley fill alluvium, and artificial fill unconformably overlying bedrock. In addition, there are a few isolate exposures of claystone bedrock. The study area is located on the south-facing hillside which slopes down from the Rocky Flats terrace surface toward Woman Creek on the south side of the Plant. Rocky Flats Alluvium caps the top of the slope, and colluvium (slope wash) covers the hillside. Artificial fill and disturbed surficial materials are present around Building 881 and south of the building to the South Interceptor Ditch. Artificial fill overlies colluvium at SWMU 130, and surficial materials are disturbed in the vicinity of SWMUs 119.1 and 119.2. Valley fill alluvium is present along the drainage of Woman Creek south of the 881 Hillside Area, and terrace alluvium occurs on the north side of the Woman Creek valley fill alluvium (wells 58-86 and 55-87).

Of particular significance with respect to contaminant transport in alluvial ground water are the presence of gravel layers in colluvial materials both unconformably overlying bedrock and near surface. These gravels were likely deposited in a south (downslope) direction by creep and slope wash erosion of the Rocky Flats Alluvium and can be expected to be elongate in the north-south direction with rather limited extent in the east-west. The gravel layers range from 1.3 feet (wells 43-87, 62-86, and 69-86) to 5.5 feet (well 59-86) in thickness.

Colluvial gravel deposits can be correlated between some of the wells and boreholes. For example, the basal gravel in well 59-86 can be traced to wells 69-86 and 8-87BR. Sand and gravel layers in well 43-87 can also be correlated with sand and gravel layers in well 4-87 and to a clay and gravel layer in well 47-87. However, the gravel layer may pinch out between the wells, based on water chemistry results.

Bedrock Materials

The Cretaceous Arapahoe Formation underlies surficial materials at the 881 Hillside Area. Six wells were completed in various zones of the bedrock during the 1986 and 1987 drilling programs. The Arapahoe Formation beneath the 881 Hillside consists of claystones with interbedded lenticular sandstones, siltstones, and occasional lignite deposits. The Arapahoe Formation was deposited by meandering streams flowing generally from west to east off the Front Range. Sandstones were deposited in stream channels and as overbank splays, and claystones were deposited in back swamp and floodplain areas. Leaf fossils, organic matter, and lignite beds were encountered within the claystones during drilling at the 881 Hillside. Contacts between various lithologies are both gradational and sharp. Based on correlation of the top of the sandstones in 5-87BR and 7-87BRA, bedrock is dipping approximately 7 degrees to the east.

Claystone bedrock was the most frequently encountered lithology of the Arapahoe Formation immediately below the Quaternary/Cretaceous contact. Weathered bedrock was encountered directly beneath surficial materials in all of the boreholes and wells, and weathering appears to penetrate between approximately two (borehole BH16-87) and 60 feet (well 62-86BR) into bedrock. The weathered claystone is also characterized by mild fracturing and thus higher hydraulic conductivities than unweathered claystone. Unweathered bedrock occurs between 37.7 (well 8-87BR) and 56 feet (well 3-87BR) below ground surface.

Arapahoe sandstones were encountered beneath the 881 Hillside in holes 59-86, 62-86, 3-87BR, 5-87BR, 6-87A, 7-87BRA, 8-87BR, and 45-87BR. These sandstones are generally composed of well sorted, subrounded to rounded, very fine- to medium-grained, poorly to moderately well cemented quartz sand with up to 10% lithic fragments. The thickness of individual sandstone beds ranged from approximately five feet (well 5-87BR) to twelve feet (well 8-87BR).

1.1.4 Ground Water

1.1.4.1 General Vicinity

Ground water occurs in both the soil and bedrock materials in the general vicinity of the Rocky Flats Plant. The major source of recharge is infiltration of incident precipitation into the Rocky Flats Alluvium, although seepage from ditches and streams also contributes to the recharge. Most of the infiltrated water flows toward the drainages on top of the relatively impermeable Upper Laramie and Arapahoe Formation claystones, or it flows to the east within the Rocky Flats Alluvium. The eastward flow is strongly controlled by the buried topography of the pediment, diverted around the bedrock highs and flowing in the buried paleo-channels. A bedrock high east of Building 881 causes diversion of ground-water flow and results in unsaturated alluvium in the area (Hurr, 1976 and Rockwell International, 1986a). The unsaturated area may also be influenced by bedrock lithology.

Some of the water in the Rocky Flats Alluvium emerges as seeps and springs at the contact between the alluvium and bedrock (contact seeps), most of which is consumed by evapotranspiration. In addition, some of the water is carried in the colluvium to the valley fill alluvium where it either flows down-valley in the alluvium, is consumed by evapotranspiration, or surfaces to augment stream flow.

During the driest periods of the year, evapotranspiration can be so intense that there is no flow in the valley fill alluvium.

Some of the ground water in the various soil deposits also enters the bedrock flow system either across the claystones to the sandstones (very small quantity flows) or directly into sandstone units in areas where sandstones (and other water bearing materials) subcrop beneath the soils. Water in the Arapahoe Formation flows generally to the east at a gradient of about 0.03 (Hurr, 1976).

1.1.4.2 881 Hillside Area

Ground water occurs in surficial materials (Rocky Flats Alluvium, colluvium, terrace alluvium, valley fill alluvium, and artificial fill) and in Arapahoe sandstones and claystones at the 881 Hillside Area. These two hydraulically connected flow systems are discussed separately below.

Ground-Water in Surficial Materials

Ground water is present in surficial materials at the 881 Hillside under unconfined conditions. Recharge to the water table occurs as infiltration of incident precipitation and as seepage from ditches and creeks. The shallow ground-water flow system is quite dynamic, with large water level changes occurring in response to precipitation events and to stream and ditch flow.

Ground water flows from the Rocky Flats Alluvium at the top of the 881 Hillside south through colluvial materials toward Woman Creek. Flow through colluvial materials appears to primarily occur in the gravel within the colluvium. At the Rocky Flats terrace edges, ground water emerges as seeps and springs at the contact between the alluvium and claystone bedrock (contact seeps), is consumed by evapotranspiration, or flows through colluvial materials following topography toward the valley fill and terrace alluviums. Once ground water reaches the valley, it either flows down-valley in the alluvium, is consumed by evapotranspiration, or discharges to Woman Creek.

Hydraulic conductivity values from drawdown-recovery tests for the Woman Creek valley fill alluvium ranged from 9×10^{-4} cm/s (900 ft/yr) to 3×10^{-3} cm/s (3,000 ft/yr) with a geometric mean of 1×10^{-3} cm/s (2000 ft/yr). Using a gradient of 0.024 ft/ft, an effective porosity of 0.1, and a mean hydraulic conductivity of 1×10^{-3} cm/s, the average ground-water velocity in Woman Creek valley fill is 250 ft/yr. Assuming that ground water flows at this velocity for about half the year, a molecule of a conservative solute would travel the 10,000 feet to the property boundary in about 80 years.

Hydraulic conductivity values are available for three wells completed in colluvium at the 881 Hillside; two are completed in gravel layers and one is completed in clayey soil wash soil (well 69-86). The test results indicate hydraulic conductivities of 4×10^{-4} cm/s for the gravel layers and 3×10^{-5} cm/s for the clayey soil. Using the maximum hydraulic conductivity value of 5×10^{-4} cm/s (520 ft/yr), an average gradient of 0.15, and an assumed effective porosity of 0.1, the maximum ground-water velocity through colluvial materials is 780 ft/yr.

Bedrock Ground-Water Flow System

The majority of ground-water flow in the Arapahoe Formation occurs in the sandstones contained within the claystones. Ground-water recharge to sandstones occurs as infiltration from alluvial ground water where sandstones subcrop beneath the alluvium and by leakage through the claystones overlying the sandstones.

There is a strong downward gradient between ground water in surficial materials and bedrock. This has been demonstrated previously at the Plant (Hurr, 1976 and Rockwell International, 1986a), and additional vertical gradient data are provided by this remedial investigation. Calculated vertical gradients range from about 2 to 0.3. Unsaturated conditions are indicated between the colluvium and the first permeable sandstone at wells 5-87BR and 59-86BR. The presence of unsaturated conditions and high vertical gradients where subsurface materials are continuously saturated indicates that the intervening material (claystone) has a very low hydraulic conductivity.

Ground-water flow within individual sandstones is from west to east at an average gradient of 0.03 ft/ft based on wells completed in the same sandstones at the 903 Pad and East Trenches Areas (Rockwell International, 1987b) and on regional data (Robson and others, 1981a). Hydraulic conductivity values were in good agreement between drawdown-recovery and slug tests. The hydraulic conductivity of the sandstones ranged from $3x10^{-6}$ cm/s to $3x10^{-4}$ cm/s with a geometric mean of $3x10^{-5}$ cm/s. The wide variation of results for a similar geologic material is reasonable given that the silt content of the sandstones varies from nill to 12 percent or more. The maximum horizontal ground-water velocity in sandstone would be about 90 ft/yr using a hydraulic conductivity of $3x10^{-4}$ cm/s, an average horizontal gradient of 0.03 ft/ft, and an assumed effective porosity of 0.1. The minimum velocity would be 0.9 ft/yr using a hydraulic conductivity of $3x10^{-6}$ cm/s and the same gradient and effective porosity. Ground water move at these rates only if the sandstone unit is continuous or has good interconnection with an adjacent unit. To date, lateral continuity of sandstone units along strike has been demonstrated to be small and only a few correlations have been made along dip (see cross sections).

1.2 NATURE AND EXTENT OF CONTAMINATION

1.2.1 881 Hillside Ground-Water Chemistry

Volatile organic compounds (VOCs) have been detected in shallow ground water in two spatially distinct portions of the 881 Hillside. In addition, there are apparently elevated concentrations of uranium, selenium, nickel, strontium and major ions in shallow ground water that may be related to activities at the 881 Hillside SWMUs or to natural geochemical variability. Ground water in the bedrock appears non-impacted by the activities at the SWMUs.

The elevated concentrations of these constituents occur in two general portions of the 881 Hillside: the area immediately south of Building 881 (SWMUs 103, 106, and 107) and the area near SWMU 119.1. Therefore, this section is divided into two subsections discussing chemical conditions in each area.

1.2.1.1 SWMUs 103, 106, and 107

Occurrence and Flow of Ground Water

Ground water occurs in both surficial materials and bedrock in the vicinity of SWMUs 103, 106, and 107. Most of the surficial materials are clayey soils consisting of natural colluvium or reworked bedrock, colluvium, and Rocky Flats Alluvium from the excavation for construction of Building 881.

The flow of water in the surficial materials is probably both slow and of small quantity because of the discontinuous nature of the various materials and their low hydraulic conductivity. Potentiometric surface maps indicate some seasonal variability of potentiometric conditions, but not enough to change the general flow pattern toward the footing drain and Woman Creek.

Chemical conditions in ground water are distinctly different from plant background conditions. These differences and implications of them are as follows.

1. Major ion chemistry indicates dominance by sodium and bicarbonate downgradient of the skimming pond in both shallow and bedrock ground water. The quality of this water is not necessarily unacceptable; TDS is approximately 500 mg/l. Vertical gradient calculations indicate continuous saturation between the shallow system and the bedrock system at this location; chemical data also suggest continuity between these systems.

2. Major ion chemistry indicates dominance by sodium, calcium and bicarbonate in the shallow and uppermost bedrock ground water in the vicinity of the three well cluster (wells 59-86BR, 8-87BR, and 69-86). The major ion chemistry in the deeper ground water at this location (well 8-87BR) is different from the more shallow ground waters, indicating poor connection with the deeper ground water, but possibly fairly good connection between the shallow ground water and the uppermost bedrock ground water.

3. Metal concentrations are generally similar to background conditions except for elevated selenium and strontium.

   Selenium was only detected in samples from the shallow and uppermost bedrock ground water at the three well cluster, supporting the conclusion that these waters are interconnected but separate from the deeper bedrock ground water. Because the uppermost bedrock ground water zone is not connected by continuously saturated material to the shallow ground water (the well even becomes dry on occasion), it is concluded that the uppermost bedrock flow zone is recharged at a subcrop slightly west of the location of the cluster. Selenium concentrations were in the range of 0.1 to 0.2 mg/l, well within the range of values reported by Moran (1976) as naturally occurring in the Golden area.

   Strontium was detected in samples from all of the wells near Building 881, even in wells with demonstrably poor connection with the shallow ground-water system. Because strontium was found in samples from all of the wells, it is concluded that its occurrence is the result of a different geochemical environment, rather than a release from one of the SWMUs. In addition, the strontium detected is not the radioactive isotope, for which analyses were also made in early 1987. Strontium concentrations are in the range of 0.4 to 1.4 mg/l much lower than concentrations in several drinking water supplies reported in Hem (1985).

4. Radionuclide concentrations are generally equivalent to background concentrations except for the uranium isotopes. The sum of the uranium-234 and uranium-238 concentrations is approximately 36 pCi/l in shallow ground water near Building 881 (well 52-87), approximately 25 pCi/l in the uppermost bedrock ground water at the three well cluster (well 59-86) and approximately 17 pCi/l in shallow ground water at the three well cluster (well 69-86) and at the downstream end of the skimming pond. These findings are significant in that:

   a. the source may be in the vicinity of well 52-87,
   b. the subcrop feeding the uppermost bedrock ground water at the three well cluster is probably located between the cluster and the Building, and
   c. most significantly, deep bedrock ground water at the end of the skimming pond (well 3-87BR) does not contain elevated uranium which implies that it is in poor connection with the overlying shallow ground water that does contain elevated uranium.

   Although uranium concentrations are elevated with respect to conditions west of the plant, they are actually quite low (less than the proposed drinking water standard of 40 pCi/l). In addition, based on isotopic ratios, the dissolved uranium is probably of natural origin and does not represent a release of the enriched uranium used in plant processes.

5. Except for the footing drain discharge and shallow ground water from well 53-87, volatile organic compounds are generally non-detectable in ground water in this vicinity. Results for well 53-87 and the footing drain discharge are shown below.

<u>PARAMETER</u>	<u>CONCENTRATION (ug/l)</u>*	
	<u>Well 53-87</u>	<u>Rooting Drain</u>
Methylene Chloride ($MeCl_2$)	21	21
1,1-Dichloroethene (1,1-DCE)	21	
1,1,1-Trichloroethane (1,1,1-TCA)	18	
Carbon Tetrachloride (CCl_4)	6	6
Trichloroethene (TCE)	23	8 (14)**
Toluene	11	12
Tetrachloroethene (PCE)		16 (128)**

* Samples collected on 11/17/87
** Sample collected on 5/26/87

The remedial investigation concludes the toluene and CCl_4 results may reflect laboratory error; therefore, if these two parameters are disregarded in comparing these waters, it appears the volatile contamination characteristics of each water are different and the volatile contamination at well 53-87 is from a local source. This contamination has not migrated to the nearest downgradient well.

6. The 881 footing drain flow (SW-45 and FDRAIN in the database) has a TDS of approximately 500 mg/l and is a calcium-bicarbonate water. These characteristics help but do not perfectly explain the higher TDS concentrations in the shallow well downgradient of the skimming pond and the dominance of calcium among some of the shallow and bedrock wells. The footing drain also contains elevated concentrations of strontium (about 0.6 mg/l) and had detectable selenium in one of the two analyses. However, uranium isotopes are within the general range of background (approximately 10 pCi/l with an uncertainty of about 35 percent). In addition, the flow contains dissolved nitrate concentrations of 8.5 mg/l as nitrogen.

There can be little doubt that the discharge from the footing drain is recharging shallow ground water on the slope below Building 881. However, the footing drain flow does not fully explain the elevated TDS concentrations, changed major ion chemistry nor the elevated uranium isotopes in the general area. Therefore, it is concluded that these changes are the result of other sources in the general area. In addition, the elevated but natural constituents (major ions, selenium, strontium and uranium) may be appropriate in the geochemical environment of the colluvium mantling the slope. This is entirely possible given that background data have not been collected from this environment.

1.2.1.2 SWMU 119.1

Occurrence and Flow of Ground Water

Ground water occurs in both surficial materials and bedrock in the vicinity of SWMU 119.1. Most of the surficial materials are clayey soils consisting of natural or slightly disturbed colluvium. The colluvium includes several thin but discrete gravel lenses that may be continuous in the downslope direction but are clearly discontinuous perpendicular to the slope. The surficial materials are directly underlain by claystones of the Arapahoe Formation.

The flow of ground water in the surficial materials is probably slow (except possibly in the gravel lenses) and of small quantity. The surficial materials are recharged primarily by infiltration. Saturated conditions appear restricted to an area centered around well 9-74 in a surficial and structural trough and this is believed to result from channeling of recharge from the small surface water drainage basin toward the SWMU on top of low permeability bedrock. The Rocky Flats Alluvium is dry upslope of the area and therefore does not provide recharge.

Flow in the surficial materials is in the downslope direction. In the downslope direction there is a fairly mild gradient in the gravel lenses that steepens downslope where the gravels have pinched-out. The steeper gradient is required to move a constant flow through the lower permeability materials. Thus, ground water is believed to discharge from the colluvium into the valley fill alluvium, although the quantity is probably small because of the low permeability of most of the colluvium. Discharge may also occur to the Interceptor Ditch during very wet periods and there is probably a small discharge to evaporation. In addition, there is probably also some flow through claystone bedrock to the underlying permeable horizons.

Description of Chemical Conditions

Chemical conditions in ground water are distinctly different from plant background conditions. These differences and implications of them are as follows.

1. The major ion chemistry is distinctly different from plant background. TDS ranged from 1200 to 1750 mg/l. The shallow ground water is about equally dominated by calcium, sodium, chloride, sulfate and bicarbonate. The bedrock ground water is characterized by the same anions but is dominated by calcium among the cations. The bedrock ground water also contains higher potassium concentrations than the shallow ground water, indicating poor connection between the two ground-water systems.

2. Metal concentrations are similar to background conditions except for elevated nickel, selenium and strontium.

   Nickel concentrations were only elevated in the shallow ground water and are actually rather low; the average concentration of about 0.2 mg/l is equal to the irrigation standard (there is no drinking water standard).

   Selenium concentrations appear to be attenuated away from the center of the SWMU, indicating that residual materials at the SWMU may be leaching selenium from the soils. The maximum selenium concentrations are consistent with levels found to be naturally occurring in the Golden area by Moran (1976).

   Strontium was found at concentrations equivalent to those found at SWMUs 103/107 in both shallow and bedrock ground water. Therefore, the strontium concentrations are considered to result from the geochemical environment rather than environmental contamination.

4. Radionuclide concentrations are generally equivalent to background concentrations except for the uranium isotopes. The sum of the uranium isotope concentrations is approximately 36 pCi/l in shallow ground water (identical to concentrations found at SWMUs 103/107) and is slightly lower in the bedrock ground water. Because the isotopic ratios indicate the uranium is probably of natural origin and because the concentrations are similar to those found elsewhere in colluvial ground water, it is concluded that these concentrations represent natural conditions and are not a release from the SWMU.

5. Volatile organic concentrations are quite high at the center of the SWMU. Samples of shallow ground water from wells 9-74 and 43-87 have the highest VOC concentrations and data for the VOCs occurring at concentrations greater than 1000 ug/l are summarized below.

VOC	Concentration (ug/l) 9-74	43-87*
1,1-DCE	703-48,000	32,687
1,1,1-TCA	4U-30,250	12,734
trans-1,2-DCE	5U	5,070
CCl_4	4U-28,000	2,170
TCE	11,000-72,000	6,999
PCE	2,400-13,200	4,259

* Sample collected 12/17/87.

However, Volatile organic compounds decrease to non-detectable concentrations within a relatively short distance (on the order of 300 feet). This rapid reduction in concentrations is in good agreement with the results of the soil gas surveys. Because these constituents are relatively mobile in ground water and would be expected to be rather widespread, it is concluded that the gravel lenses that might allow rapid migration of the compounds are discontinuous. This conclusion is supported by the steepening of the hydraulic gradient downgradient of well 4-87.

In addition, volatile compounds were non-detectable in the most-shallow permeable zone in the bedrock, indicating a poor connection between the shallow and bedrock flow systems and a lack of bedrock ground-water contamination.

1.2.2 Woman Creek Alluvium

The valley fill alluvium in Woman Creek is a thin and sparingly saturated strip of highly permeable sand and gravel. Ground-water flow velocities are quite high when there is a source of recharge, i.e., during infiltration events such as runoff or rapid snowmelt. Between recharge events, water stored in the alluvium flows down-drainage on top of the low permeability bedrock and is consumed by evapotranspiration. Recharge from contiguous colluvial deposits is insufficient to maintain saturation.

Chemical conditions in the valley fill alluvium have been investigated by installation of wells both upgradient and downgradient of the 881 Hillside Area (wells 68-86 and 64-86, respectively). The alluvial ground water near 68-86 is characterized by major ion chemistry and TDS concentrations similar to plant background, while both major ion chemistry and TDS are elevated in samples from 64-86 (TDS of approximately 500 mg/l). Samples from both of the wells contain detectable strontium concentrations of about 0.5 mg/l in samples from 64-86 (downstream well) and about 0.2 mg/l in samples from 68-86. Selenium was not detected in samples from either well. Nickel was detected in one of the two samples from well 64-86 but was never detected in samples from well 68-86. Radionuclide concentrations are within plant background ranges in samples from both wells and volatile organics were not detected.

In conclusion, these chemical data indicate a minor degradation of ground water quality in the downstream direction in the valley fill alluvium. However, the degradation takes the form of slightly elevated TDS (near the drinking water standard of 500 mg/l) and detectable concentrations of strontium. Neither of these conditions pose a hazard to the public health or the environment and may result from discharges of colluvial ground water with naturally different chemistry from ground water in the Rocky Flats Alluvium west of the plant.

1.2.3 Conclusions Regarding Ground-water Contamination

The major conclusion of this remedial investigation of ground-water conditions at the 881 Hillside Area is that there is ground-water quality degradation associated with SWMUs 103, 106, and 107 (south of Building 881) and with SWMU 119.1. The other SWMU sites at the 881 Hillside Area are not contaminating ground water. The most significant ground-water quality degradation takes the form of volatile organic contamination. The organic contamination is not areally extensive because of discontinuous stratigraphy and small quantities of ground water, and the contamination does not extend to the Woman Creek Alluvium or into permeable horizons in the bedrock.

In addition, there are apparently elevated concentrations of nickel, selenium, strontium, uranium and major ions; however, all of these elevated concentrations may result from natural geochemical variability or may reflect a leaching of naturally occurring elements from waste disposed at the 881 Hillside Area.

1.2.4 Soils

Volatile and semivolatile organic contaminants of soils exist at the 881 Hillside Area. The highest concentrations detected for chlorinated solvents was PCE at 190 ug/kg (borehole BH1-87), TCE at 150 ug/kg (BH57-87), and 1,1,1-TCA at 110 ug/kg (borehole BH57-87). These boreholes are located in the two potential contaminant source areas, i.e., south of Building 881 and at SWMU 119.1. Volatile contamination was not apparent in soils from other boreholes. However, phthalates occurred regularly and were the principal semivolatile contaminant of the soil, particularly bis(2-ethylhexyl)phthalate (DEHP). The maximum concentration of DEHP in the soil was 7,216 ug/kg in borehole 2-87.

1.2.5 Surface Water

Surface waters of Woman Creek and the South Interceptor Ditch flow to Ponds C-1 and C-2, respectively, and discharges from these ponds to Woman Creek are monitored in accordance with the Plant's NPDES permit. Sampling of the ponds indicate no VOCs are present, and radionuclides, metals, and major ions are within background levels. VOCs present in the 881 Building footing drain are diluted and/or volatilized quickly before the water enters Pond C-2. Elevated uranium 238 occurs in the South Interceptor Ditch upgradient of the 881 Hillside Area, but concentrations decrease to background levels at Pond C-2.

1.2.6 Air and Biota

An extensive air monitoring network known as the Radioactive Ambient Air Monitoring Program (RAAMP) is maintained at the Plant. Data from this network indicate that ambient air samples are well within applicable regulations and guidelines for the protection of human health and the environment for all radioactive contaminants that could possibly have originated from the Plant. No anomalous values were noted that correlated with any of the 881 Hillside Area field activities.

Available data for specific chemicals present in the ambient air at the 881 Hillside location is limited to Draeger tube readings for TCE and PCE taken during a one-day survey in March 1987 at 32 on-site locations. PCE was detected at 2 stations adjacent to an active solvent collection area (Building 952) at 2 and 3 ppm and is probably not related to past disposal activities.

The Area is not used, nor intended for use as a public or recreational area, nor for the development of any unique natural resource. No unique ecosystems or endangered species have been observed at the Plant during extensive biological studies. The biota or flora present at the area do not exhibit obvious stress. For all of these reasons, there are no ecological impacts due to contamination at the 881 Hillside Area.

1.2.7 Public Health Impacts

It is concluded that there is no imminent threat to the public health and environment by contaminants at the 881 Hillside Area. However, the travel time for a non-attenuated contaminant to reach the property boundary in the Valley Fill Alluvium is on the order of 80 years, and furthermore, the Risk Assessment (Appendix 1) documents that under these conditions an unacceptable risk could be posed to the public by consumption of contaminated alluvial ground water. Therefore, this feasibility study was undertaken to select an appropriate remedial action.

1.3 APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS

Section 121 (d) of CERCLA, as amended by the Superfund Amendments and Reauthorization Act of 1986 (SARA), requires that Fund-financed, enforcement, and Federal facility remedial actions comply with applicable or relevant and appropriate (ARAR) Federal laws, or more stringent promulgated State laws.

"Applicable" requirements are defined as those cleanup standards, or other substantive environmental protection requirements, criteria, or limitations that are promulgated Federal or State law specifically addressing the contaminants, remedial action(s), or siting limitations unique to the site destined for such a remedial action. "Applicability" implies that the remedial actions planned for the site satisfy all of the jurisdictional prerequisites of Federal or more stringent State statutes. An example of applicability is that RCRA land disposal restrictions apply to a remedial action involving excavation of soils contaminated with CERCLA hazardous substances for land disposal on site.

"Relevant and Appropriate" means those cleanup standards, or other substantive environmental protection requirements, criteria, or limitations promulgated under Federal or State law that, although not necessarily applicable, may be relevant and appropriate for the planned remedial action, contaminants of concern, or location, and address problems or situations sufficiently similar to those encountered at the CERCLA site that their use is well suited to the particular site.

1.3.1 Types of ARARS

ARARs are classified into three different categories corresponding to the varying focus of environmental statures, as follows.

Chemical Specific ARARs set health or risk-based concentration limits or ranges in environmental media for specific hazardous substances, pollutants, or contaminants. If a chemical has more than one such requirement that is ARAR, the most stringent generally applies. EPA presently considers standards developed under RCRA, the Safe Drinking Water Act (SDWA), the Clean Water Act (CWA), and Federal Ambient Water Quality Criteria for the protection of Aquatic Life as potentially ARAR; however, any more stringent standard requirement, criteria, or limitation promulgated pursuant to a State environmental statute is also potentially ARAR.

Action Specific ARARs refer to restrictions on specific remedial activities that relate to the management of hazardous substances, pollutants or contaminants. Examples are specific requirements under 40 CFR 144 for the underground injection of hazardous substances, or requirements under RCRA for the temporary storage of hazardous wastes in containers or tanks.

Location Specific ARARs set restrictions on activities depending on the characteristics of a site or its immediate environs. Examples of location-specific ARARs are RCRA limitations on the siting of hazardous waste treatment, storage, or disposal facilities, and compliance with the Endangered Species Act to avoid jeopardizing the habitat of endangered species.

Use of ARARs

ARARs may be either "applicable" or "relevant and appropriate" but not both. A determination is first made on the applicability of a Federal or State statute; then, if not applicable, a judgment is made on whether or not the statute is "relevant and appropriate". ARARs can only be developed on a site-specific basis, depending on the contaminants on site, the proposed actions, and the location of the site. Where there are no limitations or guidance on specific contaminants, actions or locations, the ARAR analysts should consult pertinent health advisories to develop a site-specific standard which is protective of human health.

CERCLA Section 121(e) exempts on site remedial action from complying with administrative aspects of Federal, State, or local permits; however, these actions must comply with the substantive aspects of these permits. That is, neither applications nor administrative review procedures are considered ARAR for actions conducted entirely on site, but the RI/FS must document that the selected alternative complies with the substantive requirements of applicable or relevant and appropriate standards.

Guidance on the Use of State ARARs

CERCLA Section 121(d)(2)(A) requires that remedies comply with "any promulgated standard, requirement, criteria, or limitation under a State environmental or facility siting law that is more stringent than any Federal standard, requirement, criteria, or limitation". The statute specifically limits the scope of potential State ARARs to those that are promulgated. State advisories, guidance, or other non-binding policies, as well as standards that are not of general application, cannot be treated as requirements under CERCLA.

CERCLA also sets specific limitations on the applicability of State requirements or siting laws that could result in a State-wide prohibition of land disposal. In order to be considered as potentially applicable or relevant and appropriate State laws must:

- be of general applicability and be formally adopted,
- be based on technical (e.g., hydrogeologic) or other relevant considerations, and
- not be intended to preclude land disposal for reasons other than protection of health or environment.

CERCLA Section 121(d)(4)(E) allows a State requirement to be waived if it has not been consistently applied by the State in similar circumstances at other remedial actions. The waiver cannot be used if the State has demonstrated the intention to consistently apply the requirement.

EPA may concur on a selected remedial alternative that does not attain a level or standard of control at least equivalent to a legally applicable or relevant and appropriate standard, requirement, criteria, or limitation providing:

1. The action selected is only part of a total remedial action that will attain such level or standard of control when completed.

2. Compliance with such requirement at that facility will result in greater risk to human health and the environment than alternative options.

3. Compliance is technically impracticable from an engineering perspective.

4. The action selected will result in a standard of performance that is equivalent to an applicable requirement through the use of another method or approach.

5. A state requirement has not been equitably applied in similar circumstances on other remedial actions within the State.

6. Initiation of a Fund-financed remedial action that does not provide a balance between available Superfund monies and the need for protection of the public health and environment at other sites where the need is more immediate.

A preliminary list of chemical-specific, action-specific, and location-specific ARARs is provided in Appendix 2. A discussion of compliance with ARARs for screened alternatives is provided in Section 4 in the institutional analysis subsections.

* Source: Interim Guidance on Compliance with Applicable or Relevant and Appropriate Requirements, USEPA, Office of Emergency and Remedial Response, July 9, 1987, Directive Number 9234.0-05.

1.4 REMEDIAL ACTION OBJECTIVES

Remedial actions for the 881 Hillside Area will address the specific environmental issues existing at the site and the following cleanup goals and objectives:

- Contain, reduce, and/or eliminate site contaminants identified as representing possible sources of exposure to human and other potential receptors.

- Reduce or eliminate exposure to site contaminants by potential receptors by controlling potential contaminant pathways.
- Demonstrate technical feasibility and environmental and cost effectiveness of the remedial actions.

To meet the stated objectives, general response actions and associated remedial technologies have been developed to address the identified sources and pathways. The site environmental issues/contaminant pathways and possible response actions are shown in Table 1-1. Technologies associated with the possible response actions are presented and screened in Section 2 of this report. The technologies that remain after screening are combined to form the remedial action alternatives for the 881 Hillside. These alternatives are screened in Section 3 to eliminate those alternatives that are more costly and do not provide significantly greater benefits. Lastly, the alternatives that remain after screening are subject to a detailed evaluation (Section 4) to provide the basis for final selection of the remedial action alternative for the 881 Hillside. A summary of the results of the detailed analyses is presented in Section 5 and the recommended remedy is presented in Section 6.

TABLE 1-1

CONTAMINANT PATHWAYS AND RESPONSE ACTIONS

Site Environmental Issues and Contaminant Pathways	Possible Response Actions
o Source release of volatile organics to ground water	- Complete or Partial Removal of Contaminated Soils - Infiltration Controls - In Situ Treatment - Immobilization - Subsurface Containment Controls
o Contaminated ground-water migration downgradient toward Woman Creek	- Ground-water Collection - On-site Ground-water Treatment

SECTION 2

SCREENING OF REMEDIAL ACTION TECHNOLOGIES

2.1 INTRODUCTION

This section is the first phase of a three-phase process to select the remedy that best satisfies the objectives listed in the previous section. The first phase is the listing and screening of the available technologies corresponding to the general response actions that deal with the environmental issues and contaminant pathways of the site. The screening process eliminates infeasible, inappropriate, or environmentally unacceptable technologies. The second phase involves assembling the screened technologies into alternatives that address the overall remedial action for the site. These alternatives are again screened. The last phase involves a detailed analysis of screened, developed alternatives that provides the basis for selection of the remedial action to be implemented. As shown in Table 2-1, there are many available technologies corresponding to the general response actions identified in Section 1.

2.2 TECHNOLOGY SCREENING

2.2.1 No Action

Under no action, the only technology is continued ground-water and surface water monitoring. Remedial activities will not be performed. Monitoring will provide information in order to track the movement and concentration of contaminants from their sources. In the event that the migration results in exceeding public health and environmental criteria near but within the facility boundary,

TABLE 2-1

RESPONSE ACTIONS AND REMEDIAL TECHNOLOGIES

GENERAL RESPONSE ACTIONS	ASSOCIATED REMEDIAL TECHNOLOGIES
No Action	o Monitoring
Complete or Partial Removal	o Off-Site Landfill
Ground-water Collection and Containment Controls	o Well Array o Subsurface Drains o Subsurface Barriers
Infiltration Controls	o Capping o Grading o Surface Water Diversion
In Situ Treatment/Immobilization	o Immobilization o Soil Flushing o Aeration o Bioreclamation o Carbon Adsorption
Ground-water Treatment	o Wet Air Oxidation o Supercritical Water o Reverse Osmosis o Biological Treatment o UV/Peroxide or UV/Ozone o Aeration Basin o Air Stripping o Carbon Adsorption

remedial action would be implemented to intercept contaminants prior to their impacting downgradient receptors. In accordance with CERCLA guidance, this technology is considered further.

2.2.2 <u>Complete or Partial Removal</u>

2.2.2.1 Soil Treatment

Although treatment of soils (generally thermal) is a class of technologies normally considered as part of organic contaminated soil excavation, the risk assessment (see Appendix 1) concluded that the contamination levels in the soils of the 881 Hillside do not pose an unacceptable risk to the public health. Therefore, these technologies have not been considered in this feasibility study.

2.2.2.2 Disposal at Off-Site Landfill

Because the NCP requires evaluation of an alternative specifying off-site disposal at a RCRA facility, this technology is presented and is retained for further consideration in the development of alternatives. The remedial investigation concluded that the radionuclide concentrations in the soils at the 881 Hillside are at or near background levels. Therefore, disposal at a RCRA mixed waste treatment storage, and disposal facility will not be required. It is possible that excavation and off-site disposal will accelerate ground-water remediation. It is noted that dust generation and some contaminant volatilization will arise, and drainage may have to be controlled.

2.2.3 <u>Ground-water Collection and Containment Controls</u>

The migration of contaminated ground-water can be controlled by ground-water withdrawal at the leading edge of the plume or by isolating the plume with subsurface barriers. Ground-water withdrawal can be accomplished by well arrays or subsurface drains. Subsurface barriers include slurry walls, grout curtains, sheet piling, and bottom sealing.

2.2.3.1 Well Arrays

Ground-water pumping techniques involve the active manipulation and management of ground water in order to contain or remove a plume or to adjust ground-water levels in order to prevent formation of a plume. Wellpoints, suction wells, ejector wells, and deep wells are all used for control of contaminated ground-water migration. The selection of the appropriate well type depends on the depth of contamination and the hydrologic and geologic characteristics of the subsurface materials.

Well systems are very versatile and can be effective under a variety of site conditions. Additional wells can be installed as needed and single wells serviced without disrupting the entire system. Pumping is most effective in homogeneous materials with relatively high intergranular hydraulic conductivities.

For plume containment and removal, either extraction wells or a combination of extraction and injection wells can be used. Injection wells can be particularly effective for gradient control of plumes in areas of relatively flat hydraulic gradients. However, injection wells require fairly regular maintenance and are subject to clogging. Well systems that combine extraction and injection wells allow for more rapid contaminant removal without greatly affecting ground-water levels. These patterns are also advantageous because the extracted water can be treated and re-injected. Contaminated ground-water containment via well arrays is appropriate for the 881 Hillside. Control of contaminant migration will minimize any off-site exposure to the contaminants. Well arrays have been retained for further consideration.

2.2.3.2 Subsurface Drains

Subsurface drains include any type of buried conduit used to collect and convey subsurface fluids. The major components of a subsurface drainage system are:

1) Drain pipe or gravel bed--for conveyance of collected fluids,
2) Envelope (drain material)--for conveying flow from the natural materials to the drain pipe,
3) Filter--to limit potential for piping and envelope clogging,
4) Backfill--material placed on top of the envelope to bring the excavation to grade with existing ground (to prevent ponding), and
5) Manholes or wet wells--points of collection from the drain pipe.

Drains function very similarly to wells and have similar uses. They can be used to contain or remove a plume, or to lower the ground-water table to prevent contact with the waste material. Drains are often constructed in conjunction with impermeable barriers. The most frequent situation is to build an impermeable barrier (clay or plastic sheeting) in the same trench but downgradient of the drain. This limits inflow of clean water to the trench from the downgradient side.

Drains can be particularly effective in low or variable hydraulic conductivity materials at relatively shallow depth. Under these conditions, development of a continuous hydraulic barrier with wells can be difficult and drains are more reliable. In addition, the operational costs of a drain system can be much less than that of a multi-well, level controlled pumping system. Drains can become prohibitively expensive to construct if they must be very deep, the subsurface materials are difficult to excavate, or the subsurface materials are geotechnically unstable.

Subsurface drains have been retained for further consideration because they can be effective in controlling contaminant migration, thus minimizing any off-site public exposure to contaminants.

2.2.3.3 Subsurface Barriers

Subsurface barriers consist of a variety of low permeability cut-off walls installed below ground to contain, capture, or redirect ground-water flow. The most common barriers are soil-bentonite slurry walls. Less common are cement-bentonite or concrete (diaphragm) slurry walls, grout curtains, and sheet piling cut-offs. Grouting may also be used to create horizontal barriers for bottom sealing. These are discussed below.

Soil-Bentonite Slurry Walls

Slurry walls are the most common subsurface barriers because they are a relatively inexpensive means of reducing ground-water flow. They are constructed in a vertical trench that is excavated under a slurry acting similarly to a drilling fluid. The slurry, usually bentonite and water, prevents collapse of the trench and forms a filter cake on the walls to prevent high fluid losses. The wall may be keyed into a low permeability horizon or may be floating (partially penetrating).

Soil-bentonite slurry walls are backfilled with soil materials mixed with the bentonite and water slurry. Soil-bentonite walls offer the lowest installation costs, the widest range of chemical compatibilities, and the lowest permeabilities. However, they have the highest compressibility (least strength, making them inappropriate for steeply sloping sites) and require a large work area. Typically, a soil-bentonite wall has a hydraulic conductivity of approximately 1×10^{-8} cm/s. The soil-bentonite slurry wall will be retained for further consideration.

Cement-Bentonite Slurry Walls

Cement-bentonite walls are generally excavated using a slurry of Portland cement, bentonite, and water. The slurry is left in the trench and allowed to harden to form the final barrier. For extremely deep trenches, the trench may be excavated under a bentonite slurry and then replaced with cement-bentonite. Cement-bentonite walls are usually finished with desiccation caps to prevent cracking.

The addition of cement to the slurry creates a semi-rigid solid of greater strength than the soil-bentonite slurry wall which can have application to more steeply sloping terrains. However, the cement has a narrower range of compatibilities with waste materials. Typically, a cement-bentonite wall has a hydraulic conductivity of approximately 1×10^{-6} cm/s. Because soil-bentonite slurry walls have lower hydraulic conductivities, cement-bentonite slurry walls are not retained for further consideration.

Diaphragm Walls

Diaphragm walls are barriers composed of reinforced concrete panels emplaced by slurry trenching techniques. They may be cast in place or precast and are capable of supporting large loads. It is possible to include diaphragm walls in soil-bentonite or cement-bentonite walls where such load carrying capacity is required, e.g., road and rail crossings. Provided the joints between panels are made properly, diaphragm walls can be expected to have hydraulic conductivities comparable to cement-bentonite walls (1×10^{-6} cm/s). For the reasons cited for cement-bentonite walls, the diaphragm is not retained for further consideration.

Grout Curtains

Grouting consists of the injection of a variety of fluids into the subsurface where they harden, resulting in reduced water flow and stronger subsurface materials. Typically, two lines of injection holes are drilled and sequentially grouted. Secondary holes are then drilled and water pressure tested to evaluate the effectiveness of the grouting. These may also require grouting to create an effective barrier. Grout curtains can be many times more expensive than slurry walls to construct and are generally incapable of attaining truly low hydraulic conductivities in either soil or rock formations. Because of limited reliability, grout curtains are seldom used where slurry walls are appropriate. For this reason, grout curtains are not considered further. However, grouting techniques are further discussed under in situ treatment (immobilization).

Sheet Piling

Sheet piles of wood, pre-cast concrete or steel can also be used to create subsurface, vertical barriers. Generally, wood is ineffective as a barrier to water and concrete is only used where great strength is required. Steel sheet piles (either webbed or straight) with interlocks at the edges are the most common. Generally, pile walls are fairly permeable when first constructed because driving causes some separation of the interlocks. However, in fine grained soils, the interlocks become plugged with fines as water moves through them. In coarser materials, the interlocks may never effectively seal. Grouting of the interlocks can be performed after installation; however, this is a costly and only marginally successful operation.

Sheet pile walls are subject to corrosion and other damaging processes that can limit the life of the walls to the range of 7 to 40 years. They frequently are not used in coarse-grained soils because pile deflections around the large particles may result in unacceptable separation of the interlocks. Because coarse-grained soils exist at the 881 Hillside, this technology is not retained for further consideration.

Bottom Sealing

Bottom sealing refers to techniques used to place a horizontal barrier beneath an existing site to act as a floor to prevent downward migration of contaminants. Bottom sealing is an experimental technology using standard grouting techniques or grouting coupled with block displacement.

Emplacement of a bottom seal by grouting involves drilling through the site, or directional drilling from the site perimeter, and injection of grout to form a quasihorizontal barrier. One technique, jet grouting, involves drilling a pattern of holes across the site to the intended barrier depth. A special jet nozzle is lowered to the base of the hole and a high pressure stream of air or water is used to erode a flat, circular cavity which is then grouted. The intersecting masses of grout form the subsurface barrier. USEPA (1985) could find no documented cases where this technology was utilized.

Block displacement is an experimental technique for vertically isolating contamination. A perimeter barrier is generally constructed by slurry trenching or grouting. Grout is then injected into specially notched holes bored through the site. The injection pressures are high enough to cause horizontal hydro-fracture and continued injection causes displacement of the overlying materials and injection of grout beneath them to form a continuous barrier. This technique has been tested in the laboratory and demonstrated at a non-hazardous site.

The claystone of the Arapahoe formation underlying the 881 Hillside is not known to have subcropping sandstones in the vicinity of the two sites under evaluation. Because the claystone has very low permeabilities, a bottom seal is not likely to provide any significant benefit in controlling vertical migration of contaminants. Therefore, bottom sealing is not considered further.

2.2.4 Infiltration Controls

2.2.4.1 Capping

Capping is used to cover buried wastes to prevent contact with the land surface and ground water. The design of caps usually conforms to the requirements of 40 CFR 264.310, which address RCRA landfill closures. In general, 40 CFR

264.310 requires minimum liquid migration through the wastes, low cover maintenance, efficient site drainage, high resistance to damage by settling or subsidence, and a cap permeability lower than or equal to the underlying liner system or natural soils. Capping is usually associated with surface water control and with ground-water monitoring and/or clean-up systems. Disadvantages of capping are the need for long-term maintenance and the uncertainty of the performance life of the cap system.

<u>Single Layer Cap</u>

Single layer caps can be constructed of a number of low permeability materials. These include:

1) compacted, low permeability soil,
2) soil-bentonite admixtures,
3) portland cement or asphalt concrete, and
4) synthetic, flexible membranes.

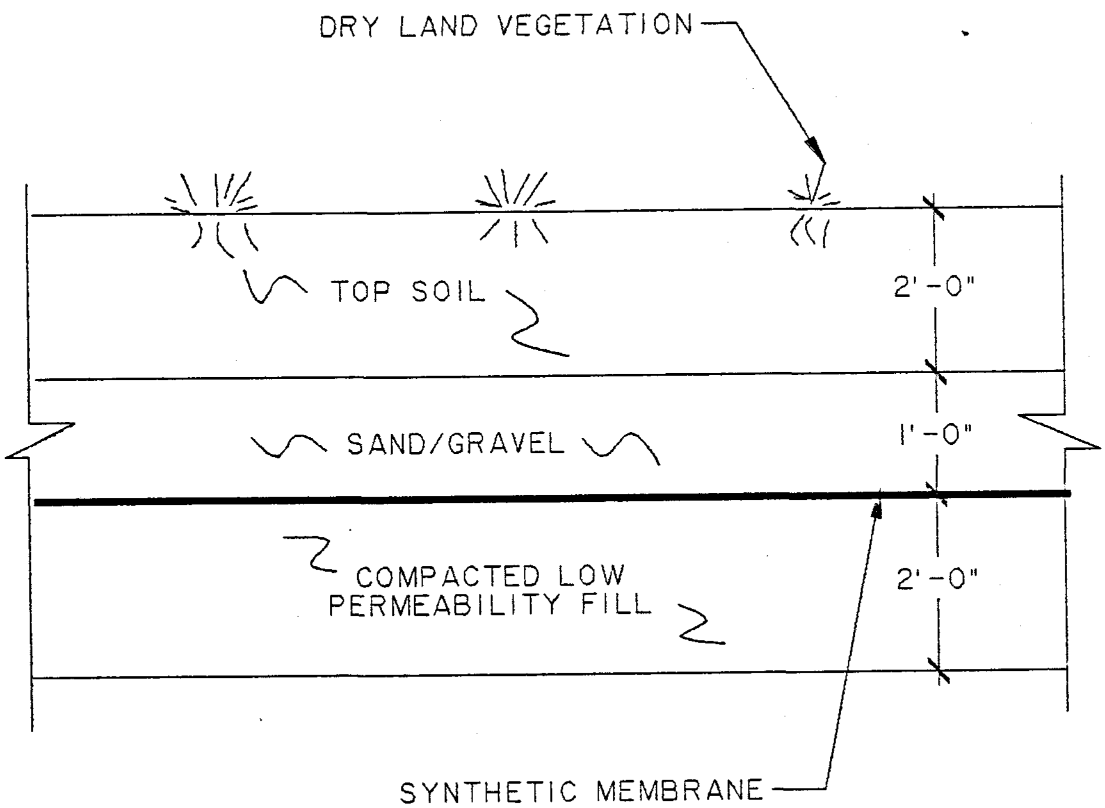
However, natural soil and admixes are not recommended because they can be disrupted by freeze/thaw cycles and exposure to the atmosphere can result in drying with consequent shrinkage and cracking. The most effective single layer caps are composed of portland cement or asphalt concrete. The thickness of these liners depends on the amount of anticipated settlement and the local weather conditions. Periodic applications of special surface treatments for asphalt and concrete liners can greatly improve their life and effectiveness.

Single layer caps are generally not acceptable except under relatively unusual circumstances. For example, single layer caps may be acceptable as temporary covers or if there is a great distance between the waste and nearest source of usable ground water. In such cases, it may be acceptable to use an extremely low permeability soil or admix buried by natural soils beneath the frost penetration depth. The overlying soils also protect the cap from drying, cracking, and mechanical damage. Because capping will be considered as long term cover, a multi-layer cap is only considered for application at the 881 Hillside.

Multi-Layer Cap

Multi-layer caps generally conform to EPA guidance under RCRA which recommends a three-layer system consisting of an upper vegetative layer, underlain by a drainage layer over a low permeability layer. A typical cap, as shown in Figure 2-1, might consist of a two-foot topsoil layer (minimum slope of 2%) underlain by a foot of sand, in turn underlain by a synthetic membrane and a two-foot layer of compacted low permeability soil. The cap functions by diverting water infiltrating the topsoil through the drainage layer and away from the underlying material.

The drainage layer is generally designed to have a permeability of at least 10^{-3} cm/s or higher. This can be achieved with SW or SP materials with less than 5 percent passing the 200 sieve. The thickness of the layer depends on the amount of water expected to infiltrate the topsoil layer. There is usually a filter fabric layer between the topsoil and the drainage layer to prevent intrusion of the topsoil into the drain. The combined thickness of the topsoil and the drainage layer must be sufficient to prevent frost heave in the low permeability layer and to protect the low permeability layer from roots.



R.SK.RCRA.CAP

ISSUE	DESCRIPTION	DATE			CLASS	JOB NO.
A	ORIGINAL ISSUE	2-10-88	REJ	NDS	SDS	986124

BLDG
ROOM
CAT.

DESIGNED JAMES	FIG 2-1 RCRA CAP SECTION	ROCKWELL INTERNATIONAL	
DRAWN DESANTIS		ROCKY FLATS PLANT GOLDEN, COLORADO 80402-0464	
CHECKED		SIZE	ISSUE / SHEET
APPROVED		A 38423-007	A / OF
RELEASE DATE 3-1-88			

COMPUTER GENERATED NO MANUAL CHANGES ALLOWED

The low permeability layer can be composed of natural soils, admixed soils, a synthetic liner, or a combination of these materials. However, a synthetic liner overlying natural soil or an admixed soil is recommended because the synthetic liner allows virtually no liquid penetration for a minimum of 20 years, while the soil layer provides redundancy should the liner fail.

Synthetic membranes have now been used in waste disposal applications for more than two decades. The membranes in use can generally be categorized as follows:

1) elastomers (rubbers):
   - butyl rubber
   - ethylene propylene rubber (ethylene propylene diene monomer, EPDM)
   - neoprene

2) thermoplastics (plastics):
   - polyethylene (PE), also available as low density (LDPE), high density (HDPE), and linear low density (LLDPE)
   - polyvinyl chloride (PVC)
   - chlorinated polyethylene (CPE)

3) combinations of elastomers and thermoplastics
   - chlorosulfonated polyethylene (CSPE -- Hypalon is a trademarked name for a CSPE)

The advantages of a polymeric membrane over other cover materials are that a variety of compounds are available which are resistant to various wastes, that sheeting is produced in a factory environment (with better QA/QC than earth fills), that the sheeting is very flexible and can withstand settlement, and that sheeting is relatively simple to install.

The disadvantages of membranes are that chemical resistance must be evaluated for each site, that seaming systems are different for each type of membrane (seams are generally considered the weak link in the system), and that many polymeric membranes are vulnerable to attach by biotic, mechanical and environmental sources. Pinholes through the membrane, a problem in the past, appear to be much less of a problem with modern membranes.

Standard practice calls for an underlying soil liner permeability equal to or less than 10^{-7} cm/s. This requires fine-grained soils (not less than 50% passing the 200 sieve). If suitable materials are not available on-site, blending of bentonite with the local soils can be used to decrease the permeability. Chemical stabilizers and cements can be added to produce lower permeabilities and greater strength. Soils may also be treated with lime, fly ash, bottom ash, and furnace slag to achieve the same ends, although these materials must be tested for hazardous constituents before use.

The establishment of a vegetative cover is a cost-effective method to stabilize the surface of a hazardous waste disposal site. Revegetation decreases erosion by wind and water and contributes to the development of a naturally fertile and stable surface environment. Also, the technique can be used to upgrade the appearance of disposal sites that are being considered for various re-use options.

2.2.4.2 Grading

Grading is the general term for techniques used to reshape the ground surface of covered disposal sites in order to reduce surface water infiltration while controlling erosion. The goals of surface grading are to:

1) reduce ponding to minimize infiltration and subsequent differential settlement,
2) reduce run-off velocities to minimize soil erosion, and
3) roughen and loosen soil in preparation for revegetation.

Manipulation of slope length and gradient are the most common grading techniques used to reduce infiltration and promote surface water run-off. A slope of at least 5 percent, but not greater than approximately 18 percent, is recommended as sufficient to promote run-off and decrease infiltration without risking excessive erosion (Lutton, 1978).

2.2.4.3 Surface Water Diversion

Dikes and berms are well-compacted earthen ridges constructed immediately upslope from and along the perimeter of disturbed areas (e.g., disposal sites). These temporary structures are generally designed to provide short term protection of critical areas by intercepting storm run-off and diverting the flow to natural or manmade drainage ways, or to stabilized outlets or to sediment traps. They are often used to protect newly constructed slopes (berms along the slope to reduce slope length) or to protect excavation operations. The two terms, dikes and berms, are generally used interchangeably.

Channels and waterways are excavated ditches that are generally wide and shallow with trapezoidal, triangular, or parabolic cross sections. Diversion channels are used primarily to intercept run-off or reduce slope length. They may or may not be stabilized. Channels are stabilized with vegetation when run-off velocity in the channel is low or stone riprap when the velocity is high. Channels are used to collect and transfer diverted water off-site or to on-site storage or treatment.

2.2.4.4 Infiltration Control Conclusion

Multi layer capping, grading and associated terracing, and surface water diversion are retained for further consideration because they will reduce infiltration and thus release of contaminants to ground-water. This will reduce contaminant concentrations in ground-water and provide increased public health protection from this source of exposure. A multi layer cap will meet RCRA standards.

2.2.5 <u>In Situ Treatment/Immobilization</u>

The risk assessment (Rockwell International, 1988) concluded that the contamination levels in the soils of the 881 Hillside do not pose an unacceptable risk to the public health. Therefore, the following in situ immobilization and treatment technologies are considered only as methods to expedite the remediation of ground-water contamination at the 881 Hillside. In situ immobilization technologies can effectively prevent the desorption of low concentrations of VOCs from the soil. Similarly, in situ treatment technologies will either destroy or contain the VOC in place or effectively flush the VOCs from the soil for collection and final treatment.

2.2.5.1 Immobilization

Immobilization or in situ solidification of buried waste can be attained by grouting or vitrification. Grouting involves injection of cement, clays, inorganic chemical grouts, or organic polymer grouts that subsequently fill the soil voids and solidify, rendering the contaminants immobilized in a solid matrix. Vitrification is the in situ application of a strong electrical current to melt the soils in place, forming a glass-like material.

Grouting

Cement is the most frequently used grout. Because of the large size of the cement particles, cement is most suitable for grouting fractured rock; however, the addition of clay or polymers can improve the range of applicability. Typically, cement grout cannot be used in fine-grained soils or rock with fractures less than 0.1 millimeters in aperture (Bowen, 1981).

Clays have also been widely used as grouts. Bentonite grout (a calcium montmorillonite) can be used alone as a void sealer in coarse sand with a permeability of more than 10^{-1} cm/s. Bentonite-chemical grouts can be used on medium to fine sands with permeabilities between 10^{-3} and 10^{-1} cm/s.

The most widely used chemical grouts are alkali silicates (sodium, potassium, and lithium silicates). Silicate grouts can be used in soils with hydraulic conductivities of less than 10^{-2} cm/s but are not suitable for grouting fractures or highly permeable materials because of syneresis (water expulsion) unless preceded by cement grouting. Also, test data indicate that silicate grouts may not be effective for fine-grained soils either.

Organic polymer grouts consist of organic materials (monomers) that polymerize and crosslink to form an insoluble gel. The organic polymer grouts include:

1) acrylamide grouts,
2) phenolic grouts,

3) urethane grouts,
4) urea-formaldehyde grouts,
5) epoxy grouts, and
6) polyester grouts.

These materials are excellent for grouting various grain size materials because they can be injected as low viscosity fluids that harden at controlled times. However, their compatibility with waste materials has not been extensively studied and many contain toxic constituents that could be released during the grouting operation.

Based on the above discussion, an organic polymer grout will be retained for further consideration as an immobilization technology. Immobilization will significantly reduce contaminant migration from the source, thus reducing any public exposure to contaminants off-site.

Vitrification

To achieve vitrification, graphite electrodes are placed into the soil and a strong current is applied which melts the soil (USEPA, 1986a). The melt occurs at increasing depths, while at the same time volatilizing the organics, which may be collected at the surface. As the soil cools, a glass-like material forms, trapping inorganic and some organic contaminants. This procedure was developed especially for immobilizing radioactive metals. In situ vitrification is not as conventional as grouting for immobilization and is also not commercially available. Limited previous applications of this technology provide inadequate verification of its feasibility. Therefore, vitrification has not been retained for further consideration.

2.2.5.2 Soil Flushing

In situ soil flushing consists of injection of a washing solution into undisturbed soil and recirculation back to the surface (USEPA, 1986b). (Alternatively, this process can be done in an above ground contactor if soils are excavated.) The contaminants are extracted as the fluids pass through the soil. Several circulations may be required. Collected contaminated water will require treatment before recycle or ultimate disposal.

Washing fluids considered appropriate for the removal of chlorinated hydrocarbons from soils at the 881 Hillside Area include water or a combination of water and surfactants. Using water as the washing fluid is contingent upon an acceptable removal rate of the contaminants from the soils. The relative effectiveness of soil flushing for the contaminants at the 881 Hillside Area can be estimated using water solubilities and octanol/water partition coefficients of the contaminants. The octanol/water partition coefficient (K_{ow}) is an estimate of a contaminant's relative tendency to adsorb to soil particles (the higher the coefficient the greater the tendency to adsorb). Table 2-2 contains a list of these estimated values for possible soil contaminants at the 881 Hillside Area (USEPA, 1981). The contaminants are grouped according to estimated relative effectiveness of the soil flushing process for each contaminant. The contaminants in the first group are estimated to be more effectively removed from the soils by the process.

It is estimated that the relative effectiveness of soil flushing with water is greatest for contaminants that have a solubility in water greater than 5×10^{-2}M and an octanol/water partition coefficient less than 2 (USEPA, 1986c), and possibly

TABLE 2-2

SOLUBILITIES AND OCTANOL/WATER PARTITION COEFFICIENTS FOR POSSIBLE CONTAMINANTS AT THE 881 HILLSIDE

Possible Soil Contaminant	Solubility (mg/l)	Solubility (M)	log k_{ow}
*1,2-DCA	8,300	8.4×10^{-2}	1.48
*t-1,2-DCE	6,300	6.5×10^{-2}	1.48
*1,1-DCE	5,000	5.2×10^{-2}	1.48
*$CHCl_3$	9,600	8.0×10^{-2}	1.97
TCE	1,100	8.4×10^{-3}	2.29
1,1,1-TCA	950	7.1×10^{-3}	2.17
PCE	150	9.0×10^{-4}	2.88
1,1,2-TCA	4,500	3.4×10^{-2}	2.17
CCl_4	800	5.2×10^{-3}	2.64

* These compounds appear to be more effectively removed by soil flushing, based solely on water solubilities, and octanol/water partition coefficients.

Note: Temperature equal to 20°C.

less than 3 (USEPA, 1985). In circumstances when these conditions are not met, the relative effectiveness of the soil flushing procedure may be enhanced with the addition of an appropriate surfactant to the flushing solution. Selection and use of a surfactant will require laboratory and pilot scale testing using actual site soils and ground water.

Bench and/or pilot scale testing of a soil flushing system is recommended because site-specific soil and ground-water conditions can have a major impact on the efficiency of the system. Soils to be treated should be uniform in nature and have a permeability of 10^{-4} cm/s or greater (Ellis, 1984). Soils that contain a high clay content may reduce the rate of percolation and thus, the effective leaching of the contaminants. Clay soils may also hinder surfactant efficiency. Surfactants may be adsorbed by the clay soils causing a reduced surfactant efficiency, and may also entrain small soil particles which may further reduce water percolation rates. Ground water effects are mainly attributable to water hardness, which will also result in a decreased surfactant efficiency.

There appear to be a number of relatively inexpensive, non-toxic surfactants available commercially to effectively aid in the removal of organic contaminants from soils. Most of the commercially available surfactants are biodegradable, although degradation under anaerobic conditions is generally slow. The washing solution, including a majority of the surfactant and possibly, a significant amount of suspended clay particles, will require collection and appropriate treatment prior to reinjection. Problems exist in effectively removing the contaminants from the collected stream without also removing a majority of the surfactants. Separation of the contaminants and the surfactants is a problem which has limited the use of surfactants in full-scale operations. Use of multiple surfactants to minimize site specific soil and ground-water effects is generally recommended. Soil flushing with treated ground water is applicable to treating the 881 Hillside Area soils and has been retained. Use of surfactants in the washing fluid may be analyzed further should washing with water alone prove relatively ineffective for the site specific conditions of the 881 Hillside Area.

2.2.5.3 In Situ Aeration

The in-situ aeration process potentially allows for the removal of volatile organic compounds from contaminated soils without the need for soil excavation (USEPA, 1985). The process removes the compounds using various configurations of permeable and non-permeable trenches, gas extraction wells, and gas collection headers. The process attempts to induce vapor transport in soils. Vapors may move vertically and laterally in soils by convection and/or diffusion. Convective movement can be controlled by altering pressure gradients within the soil. Pressure gradients in the soil can be altered by inserting gravel trenches or by producing a vacuum within the soil using a blower and gas extraction wells. Three main categories of gas control exist: passive perimeter, active perimeter, and active interior collection and recovery.

Both the passive and active perimeter gas control systems are used to prevent the migration of organic vapors outside a contaminated area. The passive system uses a gravel-filled trench equipped with a vapor barrier near its exterior perimeter to prevent gases from releasing beyond the boundary of the contaminated area. The gases migrate to the gravel trench, which provides an increased pressure gradient, and continue to move along the gravel pathway to an atmospheric vent or collection system. The low permeability membrane prevents migration outside the area boundary.

The active perimeter gas control system is also used to prevent migration of VOC vapors outside of a contaminated area. The system uses a series of gas extraction wells and connecting gas collection headers to withdraw the migrating vapors to an atmospheric vent or collection system. The gas extraction well system consists of a centrifugal blower which creates a vacuum in the well and collection headers and thus, in the surrounding soils. The vapors are pulled into the system by the creation of an increased pressure gradient. Collected gases are then either treated or vented to the atmosphere.

The active interior gas collection and recovery system is similar to the active perimeter system except that it is used throughout the entire area of soil contamination. Gas extraction wells, and associated equipment, are located throughout the area. Collected vapors are treated, if required, with either a vapor phase carbon adsorption system or an afterburner.

The preferred system for the treatment of soils at the 881 Hillside Area would be the active interior gas collection and recovery system because it provides potentially more rapid VOC removal from the soils.

The effectiveness of the system is very site specific and depends largely upon the geologic makeup of the site. The system has proven effective on soils that are sandy in nature. Soils containing a large amount of clay material, as is the case at the 881 Hillside Area, or saturated soils, are less amenable to the process. Removal of the VOCs from the soils may also be hampered by channeling of the vapors through preferential pathways. This may cause some of the VOCs to remain after the treatment process. Settlement of the soils beneath the collection system may also pose a problem as pipes may break or become filled with condensate, causing a partial or complete blockage of gas flow.

Application of this technology appears neither feasible nor effective at this site. Further evaluation of this will not be considered due to the technology's questionable technical applicability to the 881 Hillside Area.

2.2.5.4 Bioreclamation

In situ biodegradation uses in situ microbial activity to degrade hazardous organic compounds, in ground water and soils. This process serves the dual purpose of substantially reducing or eliminating sources of ground-water contamination (hazardous substances in the soil) and also limits the spread of a contaminant plume by decontaminating the ground water. Biodegradation may occur naturally under favorable conditions, but may be enhanced by increasing or depleting the subsurface oxygen constant, and by adding nutrients and/or microorganisms to the soil. These additional components are generally added to the soil and ground water using injection wells or a surface distribution process.

The contaminants at the 881 Hillside are aliphatic halogenated compounds (methanes, ethanes, or ethenes) and there are data to suggest that many of the compounds are subject to biodegradation under anaerobic conditions (USEPA, 1985; USEPA, 1986c). However, anaerobic conditions are difficult to maintain in situ. Research is being performed on in situ aerobic treatment; however, there are no known conclusive demonstrations of the effectiveness of this technology for treating soils and ground water contaminated with these organics. Therefore, this alternative has not been retained for alternative development.

2.2.5.5 In Situ Carbon Adsorption

Carbon adsorption is a well proven technology for removing volatile organic compounds from ground water. It is traditionally applied in a water treatment facility. Volatile organic compounds identified in the RI (e.g., TCE, PCE, DCE, 1,1,1-TCA, 1,2-DCA, CCl_4, and $CHCl_3$) should be effectively removed by activated carbon.

A method for deploying an in situ carbon adsorption treatment system is injection of a carbon slurry wall (Trost, 1987). This technology has only been demonstrated at the bench scale although the injection techniques are well demonstrated.

A slurry of biopolymer, carrying powdered activated carbon, is injected between the surface and the bedrock, using closely spaced injection wells creating a slurry wall approximately 50 feet thick. The slurry wall will initially reduce the ground-water flow by approximately 98 percent. After 6 to 12 months, the slurry will biodegrade leaving the carbon. The ground water will now be able to pass through the carbon wall. As the water flows through the wall, the carbon will absorb the volatile organic compounds. Microorganisms are also expected to grow on the carbon medium, and through biodegradation, assist in the removal of volatile organic compounds.

Although activated carbon is a well proven technology for removing organic contaminants from water, in situ application of this technology is still at the research and development level. Because of its unverified reliability, it has not been retained for remedial alternative development.

2.2.6 Ground-Water Treatment

2.2.6.1 Wet Air Oxidation

Wet air oxidation (WAO) is a technology for oxidation of organic substances in aqueous solutions. WAO employs high temperatures and pressures to accomplish oxidation in the aqueous phase. Water modifies the rate of oxidation and serves to control the operating temperature as a heat transfer medium. Temperatures used normally range from 175 to 325°C. Oxygen, the oxidizing agent in WAO, is provided by pressurized air. Pressures of 300 to 3000 psig are maintained in the system to prevent evaporation of the liquid phase.

Catalysts may be used to enhance the rate of oxidation permitting lower operating temperatures to achieve a certain level of contaminant destruction, or to increase the level of destruction at a given temperature. Both homogeneous and heterogeneous catalysts, including metals and metal oxides, are available for use in WAO systems.

Aqueous phase oxidation is achieved when oxygen dissolved into the water under pressure reacts with the organics present through a series of oxidative and hydrolysis reactions to form carbon dioxide and water. As an example, the complete oxidation of 1,1,1-trichloroethane would be as follows:

$$C_2H_3Cl_3 + 2\ O_2 \text{ ------> } 2CO_2 + 3HCl$$

A typical WAO system is shown in Figure 2-2. The influent is initially fed to a preheater where its temperature is elevated using the heat from the hot oxidized effluent stream. High pressure air can be added to the reactor vessel directly or the

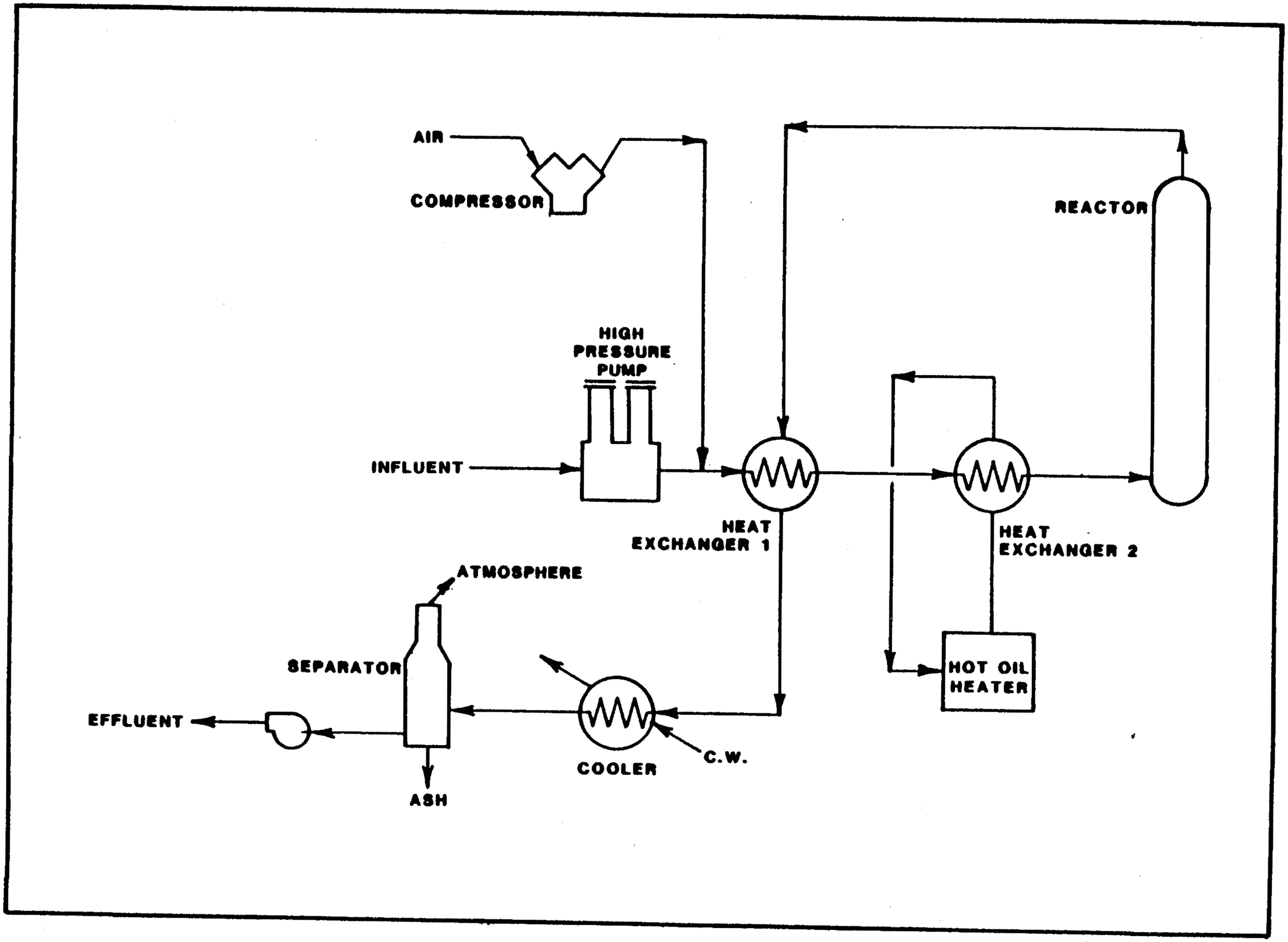


Figure 2-2: Wet Air Oxidation Process Flow Diagram

air can be added prior to entering the reactor. As the oxidation takes place in the reactor, the solution temperature will rise as the oxidized organics liberate heat of combustion. Steam, water, carbon dioxide, and nitrogen gas are removed and sent through a heat exchanger to heat the influent stream. The resulting vapor and liquid stream finally enters a separation unit. The vapors are sent through a pressure reduction valve, and can then be discharged to the atmosphere (or treated further if necessary). The oxidized water is discharged as treated effluent.

A second treatment mode is shown in Figure 2-3. In this process, powder activated carbon (PAC) is initially added to the influent stream. The organics in the waste are adsorbed onto the carbon and removed from solution. Following mixing, the solution enters a clarifier, where the PAC (with the organics) settles out as sludge. The treated effluent overflows the clarifier and the PAC sludge is treated by the WAO system described above. Regenerated PAC is recycled for treatment of the water.

The capital cost for either of the two WAO systems (with or without the PAC treatment) is estimated to be in excess of one million dollars. Although operating costs were not estimated, wastes with a chemical oxygen demand of 15,000 ppm or more are most cost effectively treated, since the oxidation of these wastes is thermally self-sustaining. More dilute wastes generally require a fuel supplement in order to maintain the water at the proper operating temperature. Because of the high capital cost and probable high operating cost of WAO relative to other treatment technologies, WAO has not been retained for alternative development.

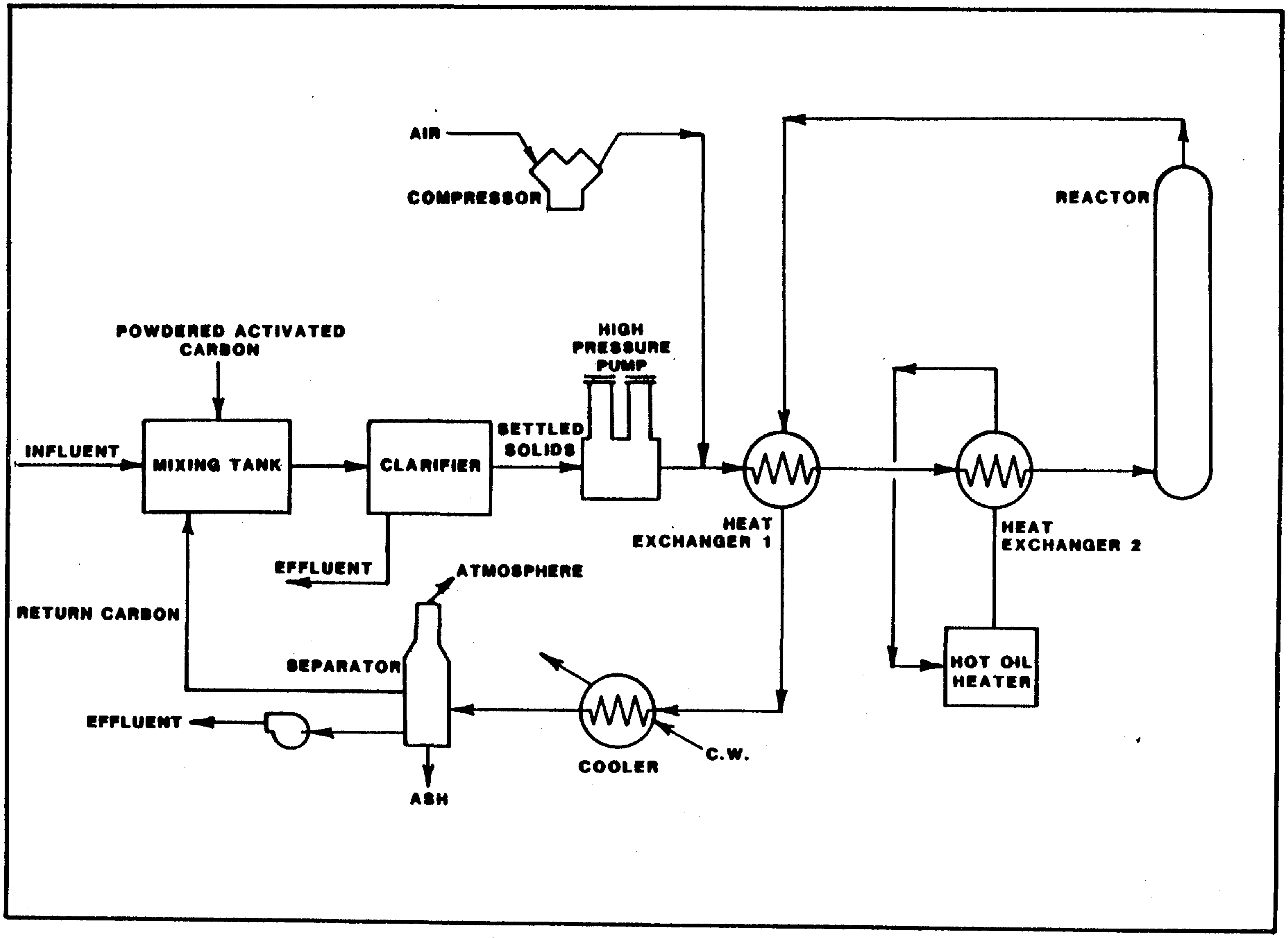


Figure 2-3: Powdered Activated Carbon/Wet Air Oxidation Process Flow Diagram

2.2.6.2 Supercritical Water

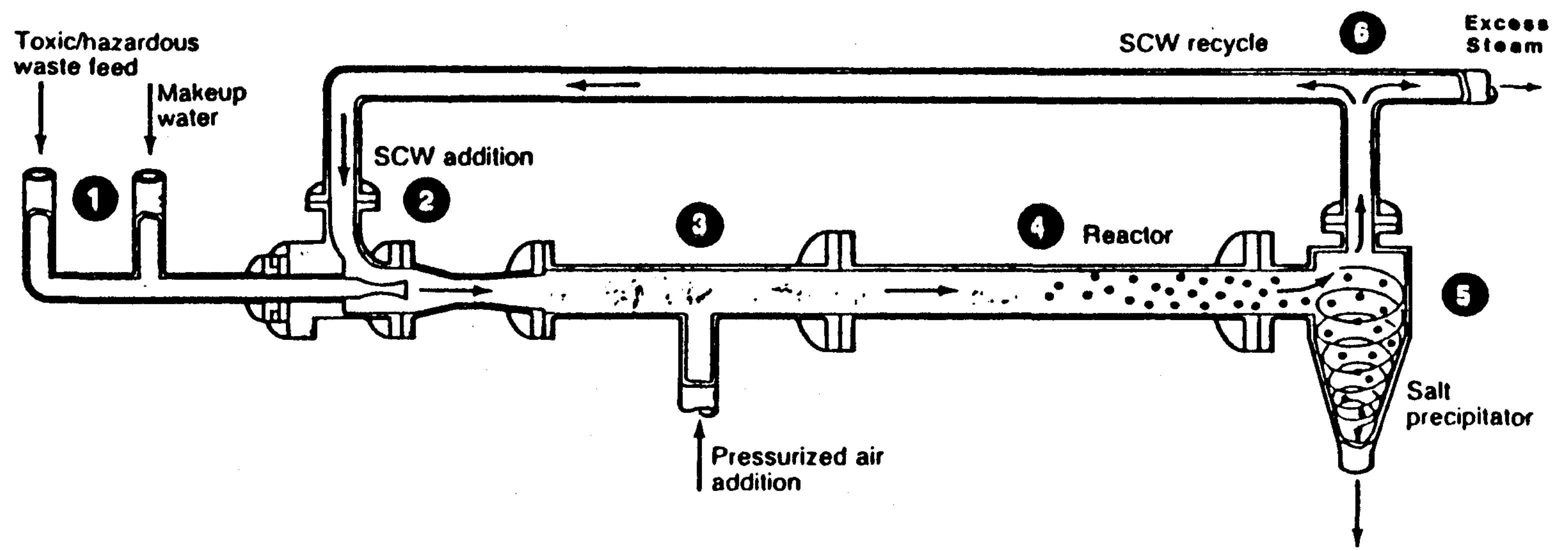
Supercritical water oxidation is a high temperature, high pressure oxidation of organics in water. This technology is based on the fact that oxygen and organic compounds are completely soluble in water at or above critical temperature (374.2^{o}C) and pressure (3,209 psig). At these supercritical conditions, liquid and vapor phases have the same density and are indistinguishable.

Organic compounds are rapidly oxidized at the supercritical condition, and all salts, metals, halogens, and other inorganics are rendered insoluble. Thus, at the critical point of water, organics are destroyed by oxidation, and inorganics and salts precipitate out and can then be separated from the water. Products from supercritical water oxidation include the treated effluent water, precipitated salts, and carbon dioxide.

To achieve supercritical conditions, a reactor vessel capable of withstanding both the high pressure and temperature is required. After the organics have been oxidized, salts and inorganics which have become insoluble must be removed in a solids separator unit. Since the process is extremely energy intensive, heat recovery from the oxidized effluent is often practical. The effluent from the process is high pressure, high temperature steam, and the only wastes produced are carbon dioxide and precipitated salts. The steam can be used for energy recovery, while the salts require proper disposal or further treatment.

A flow diagram of the system is presented in Figure 2-4. The system consists of a high level nickel alloy, corrosion resistant reactor which contains an oxidation chamber and a cyclone-type salt separator. The waste solution is pumped into the

Supercritical water reactor



1. Toxic/hazardous wastes, in solution, are fed into system automatically and under pressure; then they are mixed with makeup water.
2. SCW heats the solution to initial reaction temperature and adjusts organic content to a concentration of 2–5%, after which pressurized air is added.

3.–4. In the reactor, organics oxidize rapidly in a controlled reaction; heat evolved raises temperature to point at which salts precipitate out.
5. Reactor effluent is fed to salt separator (note cyclone arrangement) that collects the salts.
6. A portion of the SCW is recycled to the reactor; any excess can be converted to steam for other plant operations or energy needs.

Source: Michael Modell, Modar Inc.

Figure 2-4 : Modar's Supercritical Water Oxidation System

system under pressure, and is mixed with water to obtain an organic content of 2 to 5 percent. The solution is heated, and pressurized air is added to oxidize the organics. As oxidation proceeds, the heat released raises the temperature of the solution. Since the water is now in the supercritical state, salts precipitate out of solution and are separated from the effluent in the salt separator. A portion of the effluent is recycled to be mixed with the fresh influent, while the balance of the effluent can be used as steam for energy recovery.

Modar has conducted experiments with EPA's office of Research and Development and the U.S. Army Medical Bioengineering Research and Development Laboratory. These bench-scale experiments were conducted in a continuous flow, 1 gallon per day bench-scale system. Wastewater containing several chlorinated organics was used, and the results of the experiment are shown below.

	----Destruction Efficiency (%)----	
Constituent	Organic Carbon	Organic Chloride
4,4-dichlorobiphenyl	99.999	99.993
DDT	99.999	99.997
2,4-dinitrotoluene	99.999	---
trichloroethylene	99.999	N/A
methyl ethyl ketone (MEK)	99.999	---
Mixture of 1,1,1-trichloroethane, o-chlorotoluene 1,2,3-trichlorobenzene, 1,2-ethylene dichloride, 1,1,2,2-tetrachloroethylene, biphenyl, 0-xylene, and MEK	99.996	99.997
Mixture of PCB 1242, PCB 1254, transformer oil, and MEK	99.991	99.996

As can be seen, chlorinated hydrocarbons are effectively oxidized under supercritical conditions. No other performance data are available on Modar's SCW system. According to Modar, the system was designed to treat wastes containing at least 2 to 5 percent (20,000 ppm - 50,000 ppm) organics. If the waste contains at least 5 percent organics, the process can generate enough net heat to cover the operational power requirements of the system. Because the contaminated water at the 881 Hillside contains less than 0.01% organics, the energy requirements to treat it using SCW system would be very high compared to other treatment options.

No capital or operating cost data are available; however, it is likely the process would be highly energy intensive and would not be a cost effective treatment option. Typical VOC concentrations at the 881 Hillside are more than two orders of magnitude less than those for which this technology was developed. No performance data for low contaminant concentrations have been discovered. Since it is not possible to predict the effectiveness of this technology at this site, it has not been retained for alternative development.

2.2.6.3 Reverse Osmosis

Reverse osmosis is a membrane separation technology that is traditionally used for saline water conversion. During reverse osmosis, water is forced through a semipermeable membrane against an osmotic potential, i.e, that pressure differential required to prevent water molecules from migrating through the membrane from a relatively dilute to lower concentration solution. The solute rejection by the membrane is a function of the membrane and solute characteristics. The membrane characteristics include materials of construction, weave, and pore size opening while the solute characteristics include size, shape, and polarity. The molecular sieve action of the membrane is not necessarily the dominant factor in determining the solutes rejected. For example, electrostatic repulsion of ions and preferential adsorption of water molecules by the membrane are the major phenomena occurring in saline water conversion. As shown in Figure 2-5, high pressure is used to drive water and other non-rejected solutes through the membrane. The solution that passes the membrane is called the permeate and the reject solution is called the concentrate.

As the permeate is typically 10-15% of the influent flow, several membranes set up in series are necessary to maximize the flow of permeate and thus minimize the flow of concentrate requiring further treatment or disposal. One vendor of reverse osmosis units indicated the need for 12 membranes in series with provision for recycle in order to achieve a permeate flow of 75% of the total flow. As the reverse osmosis membranes are in effect molecular sieves, pretreatment of the water is necessary to remove particles greater than one micron. A high pressure pump is required to supply the major driving force of the reverse osmosis process.

Manufacturers of reverse osmosis membranes have indicated that volatile hydrocarbons with a molecular weight of 95 (characteristic of most of the chlorinated hydrocarbons at the 881 Hillside) would be rejected by the membrane. However, disadvantages include bio-fouling of the membrane, possible reactivity of the polypropylene membranes with the chemicals present in the ground water, and the large quantity of concentrate requiring subsequent treatment and disposal. Because of these limitations in system capability and these disadvantages, reverse osmosis has not been retained for alternative development.

2.2.6.4 Biological Treatment

Biological treatment can be an effective method for removal of a variety of organic compounds from contaminated water. During biological treatment, bacteria utilize the organic compounds in the waste as an energy source. The compounds are

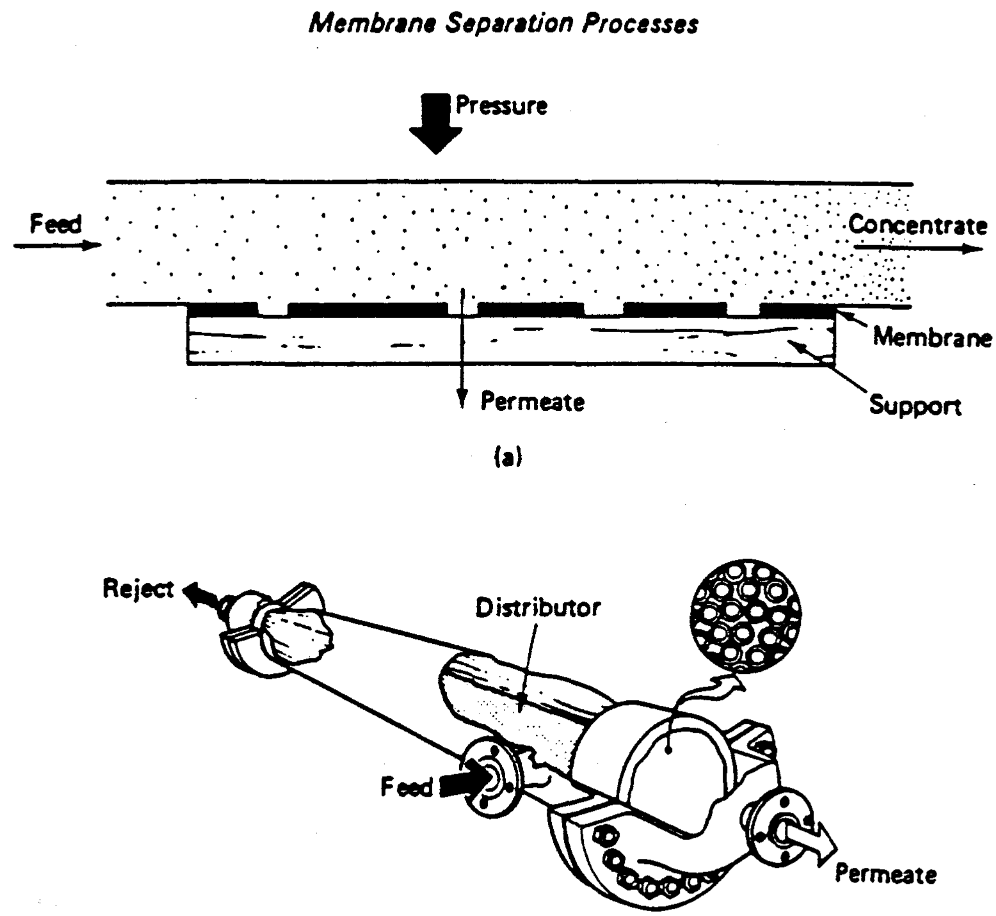


Figure 2-5: Reverse Osmosis Process

converted to either carbon dioxide and water or new cell mass. The new cell mass is continuously formed during the degradation process and must be removed from the water by settling and/or filtration. Because this technology is a biological system, temperature must be controlled or the system designed for the coldest temperature expected.

Several variations on the design of biological treatment systems are available. Systems can either be aerobic or anaerobic, and free suspension or fixed film. For reasons previously stated under in situ bioreclamation, anaerobic biological treatment would be most appropriate.

In fixed film biological treatment, generally most appropriate for small scale systems, bacteria adhere to the surface of a supporting medium. As contaminated water passes over the film of bacteria, organics are consumed by the bacteria generating more biomass. The increase in biomass causes the bacterial film thickness to increase. Eventually the film thickness results in a layer of cells nearest the medium becoming starved of oxygen and nutrients. These cells lose their ability to adhere to the surface, and shear forces in the water cause sloughing of the bacterial film. This sloughing and growth is dynamic in nature such that, under proper operating conditions, the bacterial mass within the reactor remains constant. The bacteria that slough must be removed through a solids separation process, e.g. sedimentation and/or filtration.

The chlorinated hydrocarbon compounds found in the contaminated hillside water either have slow biodegradation rates, or data do not exist that indicate their biodegradeability. In general, the more chlorinated the compound, the less likely the compound can be biodegraded in a reasonable time, if at all. Some of these compounds found at the Hillside may also be toxic to the bacteria.

Although the direct treatment cost can be low relative to other treatment technologies, it should be noted that biological systems have high maintenance requirements, require disposal of a sludge which in this case would be considered a hazardous waste, and can be unreliable by virtue of the complex nature of the system. For example, organic loading can change dramatically over the course of days or even hours, and toxic compounds may be introduced to the system sporadically, resulting in upsets. Because of these potential operational problems and the lack of supporting data for biodegradation of all the chlorinated hydrocarbons present in the ground water at the 881 Hillside, biological treatment is not retained for further evaluation.

2.2.6.5 Ultraviolet/Ozone and Ultraviolet/Hydrogen Peroxide Oxidation

Chemical oxidation is an effective method of destroying most organic compounds present in water and wastewater. A variety of chemical oxidants are commercially available. Listed below are oxidants ordered according to their oxidation potential. The higher the oxidation potential, the stronger the oxidant.

OXIDATION POTENTIAL OF OXIDANTS

SPECIE	OXIDATIVE POTENTIAL (VOLTS)
Fluorine	3.03
Hydroxyl Radical	2.80
Atomic Oxygen (singles)	2.42
Ozone	2.07
Hydrogen Peroxide	1.78
Perhydroxyl Radical	1.70
Permanganate	1.68
Hypobromous Acid	1.59
Chlorine Dioxide	1.57
Hypochlorous Acid	1.49
Hypoiodous Acid	1.45
Chlorine	1.36
Bromine	1.09
Iodine	0.54

With the exception of fluorine, hydroxyl radicals ($\cdot OH$) have the highest oxidation potential of any commercially available oxidants. Hydroxyl radicals can be generated very efficiently by exposing ozone (O_3) or hydrogen peroxide (H_2O_2) to ultraviolet (UV) light at wavelengths of 400 nm or less:

$$O_3 + H_2O \xrightarrow{UV} O_2 + 2\ \cdot OH$$

$$H_2O_2 \xrightarrow[<400\ nm]{UV} 2\ \cdot OH$$

The hydroxyl radicals formed are highly effective at oxidizing organics in water to carbon dioxide and water. For example, formic acid (HCOOH) reacts with hydroxyl ions as follows:

$$HCOOH + {}^{\cdot}OH \text{ ----------> } H_2O + HCOOO^{\cdot}$$

$$HCOO^{\cdot} + {}^{\cdot}OH \text{ ----------> } H_2O + CO_2$$

Ozone or hydrogen peroxide alone can also be used as an oxidant, but as shown in the above list, they have a lower oxidation potential than the hydroxyl radical, and are thus a weaker oxidant. Ultraviolet light serves a dual purpose in UV/H_2O_2 or UV/O_3 oxidation systems. In addition to converting hydrogen peroxide or O_3 to hydroxyl radicals, many organics absorb UV light and become more reactive to chemical oxidation.

Partial oxidation of the organics present will result if the concentration of the oxidant is insufficient. For example, aromatic hydrocarbons are first oxidized to organic acids before being completely oxidized to carbon dioxide and water. Therefore, it is important to supply enough oxidant to completely oxidize all organics present. For ground water containing low concentrations of volatile organics, partial oxidation is not considered a problem.

The efficiency of the UV/Ozone/Peroxide system depends upon several parameters, including:

- o type and concentration of organic and inorganic contaminants (VOCs, oil and grease, metals, bicarbonate, etc.)
- o turbidity of the water
- o water temperature
- o UV, ozone, and H_2O_2 dosages
- o mixing efficiency
- o use of catalyst

Bench-scale or pilot-scale studies are necessary to optimize the system efficiency. Performing such tests provide the necessary results to determine the oxidant dosage, UV radiation required, and necessary reaction times to achieve the desired effluent quality.

Ultraviolet light can be used in conjunction with ozone, peroxide, or a combination of the two oxidants. A system marketed by Ultrox International utilizes ultraviolet light, ozone, and possibly a small quantity of hydrogen peroxide. In this particular UV/Ozone/Peroxide system, hydrogen peroxide may be added to the contaminated water, and then the water is pumped into a UV reactor where the ozone is bubbled through the water. Ozone that is not solubilized in the water is catalytically converted to oxygen before it is released to the atmosphere. The total system consists of a UV/oxidation reactor, ozone generator with air compressor and air preparation system, controls, ballasts, ozone decomposer, and H_2O_2 feed system.

Ultrox International has provided performance data on their UV/Ozone/Peroxide oxidation system for a pilot-scale testing of the system at the Bendix Plant in Kansas City. The pilot study indicated that the VOCs could be effectively destroyed to below detectable limits of 10 ppb. Test results for the Bendix Plant pilot study are shown in Table 2-3.

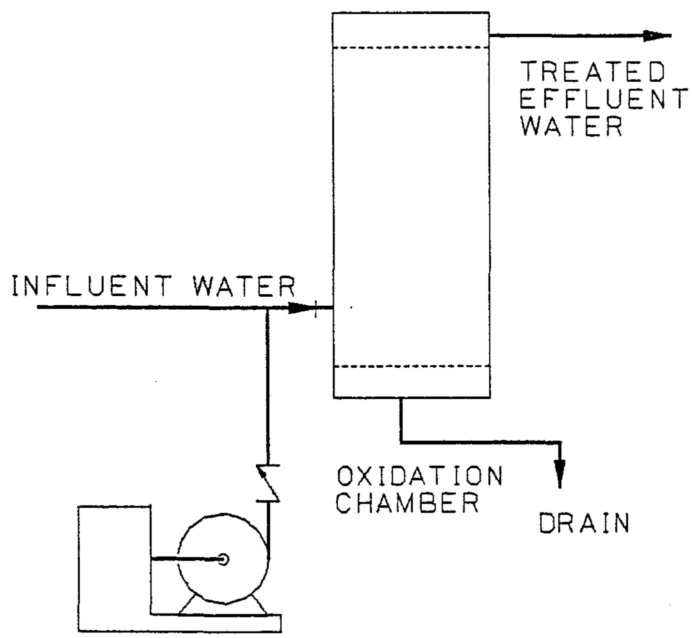
Peroxidation Systems, Inc. utilizes a system that combines UV light and hydrogen peroxide. Figure 2-6 shows a flow diagram for the treatment of water using the UV/Ozone/Peroxide system. Capital equipment for the UV/Peroxide system includes a UV reactor, an H_2O_2 feed tank, and a ballast enclosure. Performance data has been provided on the UV/H_2O_2 oxidation system for several different pilot-test cases of ground-water treatment. In almost all cases, it was shown that greater than 95% oxidation of chlorinated hydrocarbon volatiles or semivolatiles could be achieved

TABLE 2-3

PILOT STUDY RESULTS FOR UV/OZONE/PEROXIDE AT THE BENDIX PLANT*

	TCE	TCA	1,2-t-DCE	PCE	$MeCl_2$	Vinyl Chloride
Feed	418	98	<10	52	62	<10
Run A	<10	<10	<10	<10	<10	<10
Feed	470	166	16	96	<10	72
Run B	<10	<10	<10	<10	<10	<10

* Concentrations in ug/l



NOT TO SCALE

R.SK.UV.PEROXIDE.SYSTEM

ISSUE	DESCRIPTION	DATE			CLASS	JOB NO.
A	ORIGINAL ISSUE	2-10-88	RE J	ND S	SDS	986124

DESIGNED JAMES
DRAWN DESANTIS
CHECKED
APPROVED
RELEASE DATE 3-1-88

FIG 2-6 UV/PEROXIDE SYSTEM

ROCKWELL INTERNATIONAL
ROCKY FLATS PLANT GOLDEN, COLORADO 80402-0464

SIZE		ISSUE	SHEET
A	38423-012	A	OF

BLDG.
ROOM
CAT.

COMPUTER GENERATED NO MANUAL CHANGES ALLOWED under some combination of H_2O_2 dose and energy input (reaction time). Test results for waters containing chlorinated hydrocarbons are shown in Table 2-4.

It is estimated the capital cost for a 30 gpm UV/Ozone/Peroxide system will be on the order of $135,000. This cost includes a 725 gallon 304SS reactor vessel, a 28 lb/day ozone generator with air compressor and air preparation system, controls, ballasts, ozone decomposer and H_2O_2 feed system. The reactor is baffled into six sections and contains up to 72 65-watt UV lamps in quartz sheaths. In contrast, it is estimated the capital costs for a similar UV/Peroxide system would be on the order of $50-70,000. The cost would include an 80-gallon 316SS reactor tank, H_2O_2 feed system, ballast, and electrical controls. The decrease in capital expenses can be attributed largely to the ozone generation and decomposition equipment (not required in this system). Also, this system requires only four UV lamps.

Operating costs for the UV/Ozone/Peroxide are estimated to be approximately $1.14/1000 gallons of treated water, dependent upon results of actual bench or pilot scale testing. Assuming a continuous flow of 10 gpm, the yearly operating costs, excluding maintenance and capital amortization, are approximately $6,000. Operating costs for the UV/Peroxide system have also been estimated to be $5,740/yr. Both systems are relatively maintenance free and should require minimal manpower to operate. It is estimated the UV lamps will require replacement every year at a nominal cost. Bench-scale or pilot-scale testing are necessary to provide more accurate cost estimates because waste characteristics have a large impact on the overall costs.

Initial evaluation of the UV/Ozone and UV/Peroxide systems indicate that both systems will provide treated effluent water that meets chemical ARARs for organics. However, further evaluation of only the UV/Peroxide system will be

TABLE 2-4

UV/H_2O_2 OXIDATION OF VOLATILE ORGANIC CONTAMINANTS IN GROUND-WATER LEACHATE

	----------Reaction Time, Hours-----------				
	0	0.5		2.0	
pH	7.4	7.2		7.8	
UV Dose, watt hr/l	---	115		460	
H_2O_2 Dose, mg/l	---	145		581	
Cost of H_2O_2, $/1000 gal*	---	0.85		3.4	
Cost of Energy, $/1000 gal*	---	21.00		85.4	
Total, $/1000 gal	---	21.85		88.4	
Contaminant					
TOC, mg/l	58.1	47.7	(16.5)**	9.5	(83.4)**
COD, mg/l	525	195	(62.9)	100	(81.0)
Benzene, ug/l	6	3	(50)	1	(83.3)
Toluene,ug/l	18	ND	(100)	ND	(100)
Xylene, ug/l	84	ND	(100)	ND	(100)
Acetone, ug/l	56	330		190	
MEK, ug/l	400	140		21	(94.8)
Methylene Chloride, ug/l	120	44	(63.3)	ND	(100)
1,1-Dichloroethane, ug/l	20	ND	(100)	ND	(100)
1,1-Dichloroethene, ug/l	66	18	(72.7)	ND	(100)
Trans-1,2-Dichloroethane, ug/l	1	ND	(100)	ND	(100)
1,2-Dichloroethane, ug/l	710	660	(7.0)	16	(97.7)
1,1,1-Trichloroethane, ug/l	480	58	(87.9)	2	(99.6)
Trichloroethylene, ug/l	ND	24		5	

* H_2O_2 @ $0.70/# for 100% solution and energy @ $0.05/KWH
** ( ) = % Removal

conducted. The UV/Peroxide system requires a smaller initial capital investment, is potentially less maintenance intensive (due to fewer UV lamps and no ozone generation equipment) and does not require the use of ozone, a toxic gas. Since both systems are examples of identical technologies and peroxide is the preferred reagent, UV/Peroxide water treatment technologies have been retained for further detailed evaluations in Section 4.

2.2.6.6 Aeration Basin

Aeration reduces the concentration of hazardous volatile organic compounds in water by transferring these compounds to the air (USEPA, 1984). The process is based on the tendency for the air-water system to establish chemical equilibrium between the liquid and gas phases. Unless the air is saturated with the volatile organic compounds (equilibrium), the water-to-air diffusion rate will exceed the air-to-water diffusion rate. By exposing the water to the atmosphere, the air volume becomes practically infinite, and cannot be saturated. Since the water-atmosphere system will never reach equilibrium, all of the volatile organic contaminants should, theoretically, diffuse from the water to the air. Diffusion takes place at the water surface (water-air interface) only. The action of aeration (mixing) exposes more water surface area to the air. This increases the water-to-air diffusion rate, thereby accelerating the rate of decontamination. Aeration is accomplished by stirring, injecting air into the water, or mechanical dispersion of the water into droplets.

"Volatile hydrocarbon" is a relative term denoting compounds with relatively high vapor pressures or Henry's Law constants. Henry's Law Constant (H_a) is the ratio of the gas phase and liquid phase concentrations for a compound at equilibrium. A higher H_a indicates greater partitioning of the compound into the gas phase relative to the liquid phase, and therefore greater stripping removal efficiency. H_a's for various HSL volatiles detected in alluvial ground water at the 881 Hillside are shown in Table 2-5 (USEPA, 1981). As can be seen, only 1,2-DCA and 1,1,2-TCA have relatively low H_a's; however, they occur at concentrations which are orders of magnitude lower than the other volatile organics.

Aeration in a basin can be accomplished by injecting air into the water (diffused air-aeration) or by surface agitation (mechanical aeration). Aeration basins are susceptible to freezing at low temperatures. Construction of structures to protect the basins from cold may be needed in areas where winters are severe. Chemical or biological slime may also develop within an aeration system adversely affecting the efficiency of the operation. Because aeration will generate off-gases, an air pollution permit and/or off-gas treatment may be needed.

EPA compared costs of an aeration basin with those of packed towers (see Section 2.2.6.7 on air stripping) with the same efficiency, and found the costs of aeration basins to be two to six times higher. Costs are expected to double if the addition of air emission controls is required. An aeration basin was not retained for alternative development, principally because packed tower air strippers have the same effectiveness at a substantially reduced cost.

2.2.6.7 Air Stripping

Like aeration, air stripping causes the mass transfer of volatile organic compounds from a dilute aqueous solution to a continuously flowing air stream (USEPA, 1986b). Many types of air strippers exist, but the most efficient for the removal of volatile compounds from ground water is the packed bed tower with

TABLE 2-5

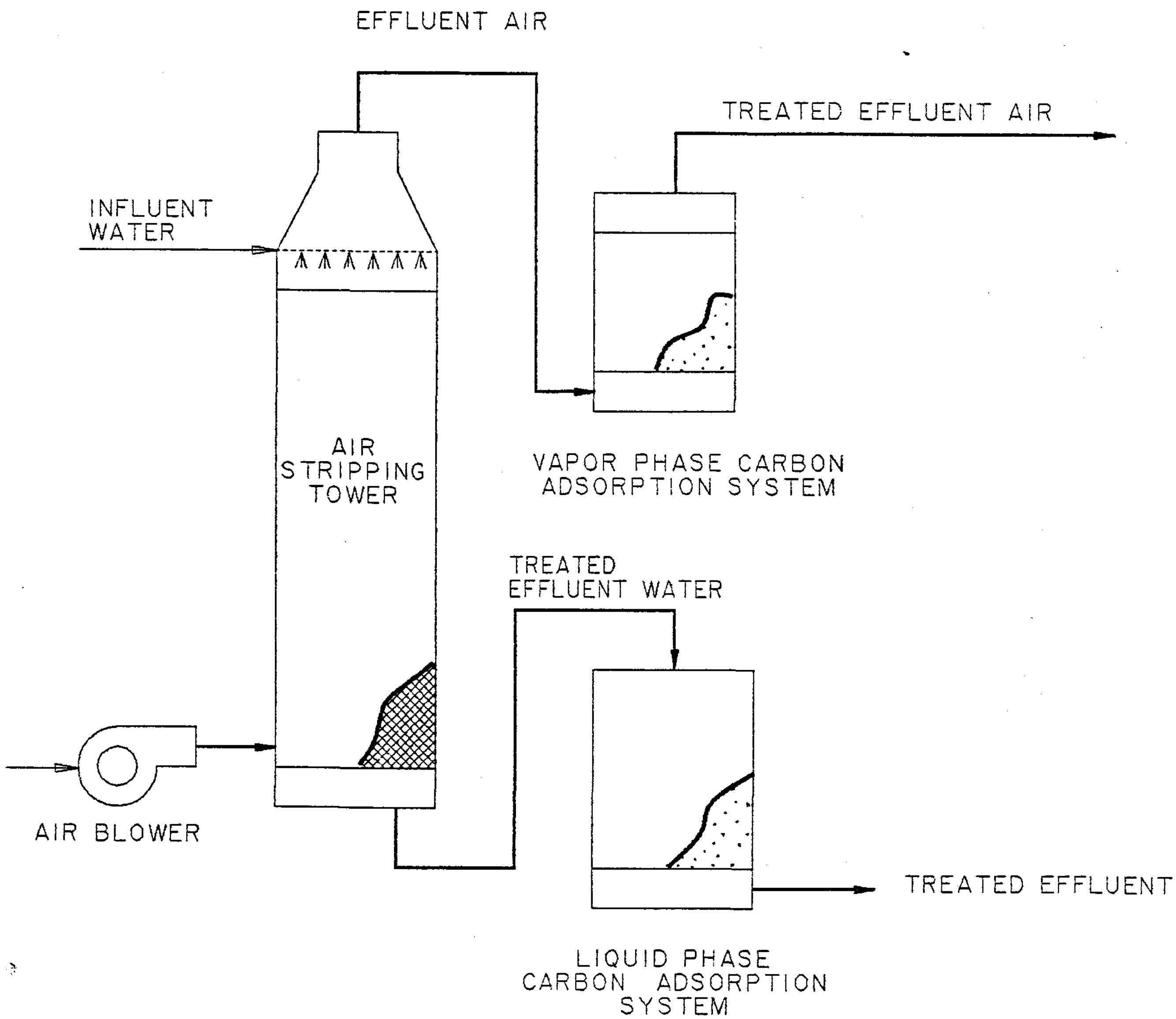
HENRY'S LAW CONSTANTS (Ha)
FOR POSSIBLE CONTAMINANTS
AT THE 881 HILLSIDE

Compound	Ha (dimensionless) @ 25^{o}C
CCl_4	1.26
1,2-DCA	0.05
1,1,1-TCA	0.21
1,1,2-TCA	0.04
1,1-DCE	0.63
t-1,2-DCE	0.22
PCE	1.20
TCE	0.49
$CHCl_3$	0.14

countercurrent flow (Knox, 1984)(see Figure 2-7). Water containing VOCs is fed to the top of the tower and distributed over the column packing material, while air is blown through the tower from the bottom. Treated effluent is drawn off the bottom, while the air, now containing the volatile compounds, exits the top of the column, and may be conveyed to a vapor phase carbon adsorption system or an afterburner if required by local air pollution regulations. The column packing material may need occasional flushing with hypochlorite or with other acidic solutions to remove residuals or bacteria that may collect in the system.

Enhanced mass transfer occurs with increased contact between phases and is optimized by selecting packing materials with large surface area. An increased concentration gradient between the two phases also results in an increased rate of mass transfer. High air to water flow rate ratios are used to physically remove increasing vapor phase concentrations, resulting in concentration gradients that remain as large as possible. Temperature also has an effect on the rate of mass transfer. An increase in the system temperature results in a corresponding increase in both the Henry's Law Constant and the rate of mass transfer. This is the basis for steam stripping, which is used mainly for the removal of less volatile organic compounds. Increased capital and operating costs associated with steam generation and heat recovery, coupled with a minimal enhancement of system efficiency for removal of contaminants in ground water at the 881 Hillside render steam stripping less cost effective than air stripping.

A proposed preliminary design of an air stripping system for the 881 Hillside area consists of a 22-inch diameter fiberglass reinforced plastic column approximately 35 feet in height (Duall Industries, 1988). The packing medium consists of two-inch polypropylene pall rings or tri-packs. An influent water flow rate of 30 gallons per



NOT TO SCALE

R.SK.AIR.STRIPPING

ISSUE	DESCRIPTION	DATE		CLASS	JOB NO.
A	ORIGINAL ISSUE	2-10-88	REJ NDS	SDS	986124

DESIGNED JAMES
DRAWN DESANTIS
CHECKED
APPROVED
RELEASE DATE 3-1-88

FIG 2-7 AIR STRIPPING

ROCKWELL INTERNATIONAL
ROCKY FLATS PLANT GOLDEN,COLORADO 80402-0464

SIZE		ISSUE	SHEET
A	38423-013	A	OF

BLDG.
ROOM
CAT.

COMPUTER GENERATED NO MANUAL CHANGES ALLOWED

minute may be treated, with air-to-water flow rate ratios of 50:1 possible. A conservative estimate of the removal efficiency is 99+%. A carbon adsorption unit following an air stripper is recommended to provide a backup system for surges in flow or contaminant concentrations.

Air flowing from the stripper will contain a low level of contaminant concentrations and may require treatment to meet air emission standards. A vapor phase carbon adsorption system is the recommended treatment for air effluent. Air exiting the air stripper would pass through a vapor phase carbon unit containing 1,500 pounds of activated carbon. Vapor phase carbon adsorption is reported to have a 4 to 10 times greater capacity than liquid phase carbon adsorption, although actual effectiveness of the system may be less. Removal efficiency is dependent upon flow rates, relative humidity, types of organics present, and their relative concentrations. A heater and blower may be required to lower the relative humidity in order to optimize the removal efficiency. When the carbon is spent, it can be removed and transported off site for regeneration.

The air stripping process is effective for the removal of volatile organics from ground water. Computer modeling or lab scale testing may be used to optimize the design of the system. Types and amounts of wastes, system flow rate, desired removal efficiency, amounts of suspended solids and dissolved iron, manganese, and carbonates are some of the important system variables to consider. The system is generally designed to obtain the desired removal efficiency for a contaminant which occurs at a high concentration and has a low Henry's Law Constant. Important design variables to evaluate are size of column, type of packing, and air to liquid flow ratio. Removal efficiency can be increased by increasing the size of the column, using more efficient packing, increasing the air-to-liquid ratios, or using multiple columns.

Capital cost for an air stripping unit capable of obtaining 99+% removal efficiencies is approximately $12,500. Use of a liquid phase carbon adsorption unit as described in Section 2.2.6.8 is recommended with this system to provide a backup for surges in influent water flows and concentrations. Treatment of the off-gas may be required to meet regulatory air emission standards. Use of a vapor phase carbon adsorption system to remove the low level of contaminants from the air stream is suggested. Capital costs for an air stripper equipped with a heater and blower is likely to be on the order of $14,500.

The air stripper requires minimal manpower; therefore, its operating costs are also minimal. Operating costs are largely associated with liquid and vapor phase carbon adsorption systems. Carbon replacement and disposal costs are derived in Section 2.2.6.8 and have been scaled down to estimate costs for this system. Liquid phase carbon will require replacement approximately every three months, while the vapor phase carbon unit will require replacement approximately every seven months. Costs for a disposable 1,000 pound liquid phase carbon adsorption unit is $3,500, while the 1,500 pound vapor phase carbon unit will cost approximately $8,000 (includes regeneration and shipping costs). Total carbon replacement costs are estimated to be $24,000 per year (see Section 2.3 for detailed costs).

Air stripping is a viable alternative for treatment of the ground water at the 881 Hillside area. All of the organic compounds found in the ground water are volatile and are effectively removed by aeration. Emission of untreated off-gas to the atmosphere, may be within air pollution emission standards thereby further reducing operation costs. Therefore, the air stripping unit is retained for detailed alternative evaluation (Section 4) for the 881 Hillside.

2.2.6.8 Activated Carbon

Activated carbon adsorption systems are commonly used to remove organic contaminants from water and gas streams. Activated carbon is produced from the carbonaceous residue from the pyrolysis of wood, coal, or nut shells. Hydrocarbons remaining in the carbonaceous residue are then oxidized by steam or air (activation) which creates the highly porous structure of the carbon (Cheremiswoff and Ellerbusch, 1980).

Adsorption is a process which involves the interphase accumulation or concentration of substances at a surface or interface. Adsorption is usually described in terms of surface tension or energy per unit area. Interior molecules of solids are subjected to equal forces in all directions while molecules at the surface are subject to unbalanced forces; thus, foreign molecules become attached to the surface. This phenomenon is known as physical adsorption, or Van der Waals adsorption. Adsorption may also be the result of chemical interaction between the activated carbon and the adsorbed substance. An adsorption equilibrium is established when the concentration of contaminant remaining in solution is in a dynamic balance with that at the surface. In general, the higher the molecular weight and the lower the polarity of the molecule, the greater the adsorption of the compound on activated carbon (Hassler, 1974). The surface area of activated carbon is roughly 500-1,500 m^2 per gram (Faust and Aly, 1983). As a result, a relatively small amount of activated carbon is capable of treating a large volume of waste.

Once the adsorptive capacity of activated carbon has been reached, the used carbon must be regenerated. Regeneration is usually achieved by oxidizing the spent carbon at high temperatures in a furnace or by steam desorption.

Carbon is a highly effective method for the removal of volatile organic compounds from ground water. Effective removal to non-detectable levels is common; however, adsorption capacity is compound specific. The amount of adsorbate (organic molecules) that will collect on a given quantity of carbon in equilibrium with a given concentration in solution is commonly calculated using the empirical Freundlich (isotherm) formula:

$X/M = KC^{1/N}$, where

X = mass of organic material adsorbed,
M = mass of carbon
X/M = mass of organic material adsorbed per unit mass of carbon,
C = the equilibrium concentration of adsorbate in solution (mass/volume),
K,N = constants specific to the adsorbate

While the Freundlich equation may be used to estimate breakthrough, column testing is preferable because Freundlich equation results are based on static conditions, and column test results are based on dynamic conditions and reflect parameters such as flow rates and actual water chemistry. The information collected during column tests may be used to design a full-scale treatment system.

Calgon Carbon Corporation performs a variation of the standard column test known as the Accelerated Column Test (ACT). An ACT was performed for Rocky Flats using a five-gallon water sample containing approximately 9 parts Building 881 footing drain water and 1 part well 9-74 water. This ratio was chosen to approximate the average concentration that will enter the treatment plant. In this test, the 9:1 mixture was passed through a short, thin column filled with carbon. The breakthrough results and the concentrations of the water mixture prior to the ACT are shown in Table 2-6. Breakthrough occurred when the effluent exceeded 1 ppb. As can be seen, methylene chloride and 1,1 dichloroethane have low carbon adsorptive

TABLE 2-6

ACCELERATED COLUMN TEST RESULTS

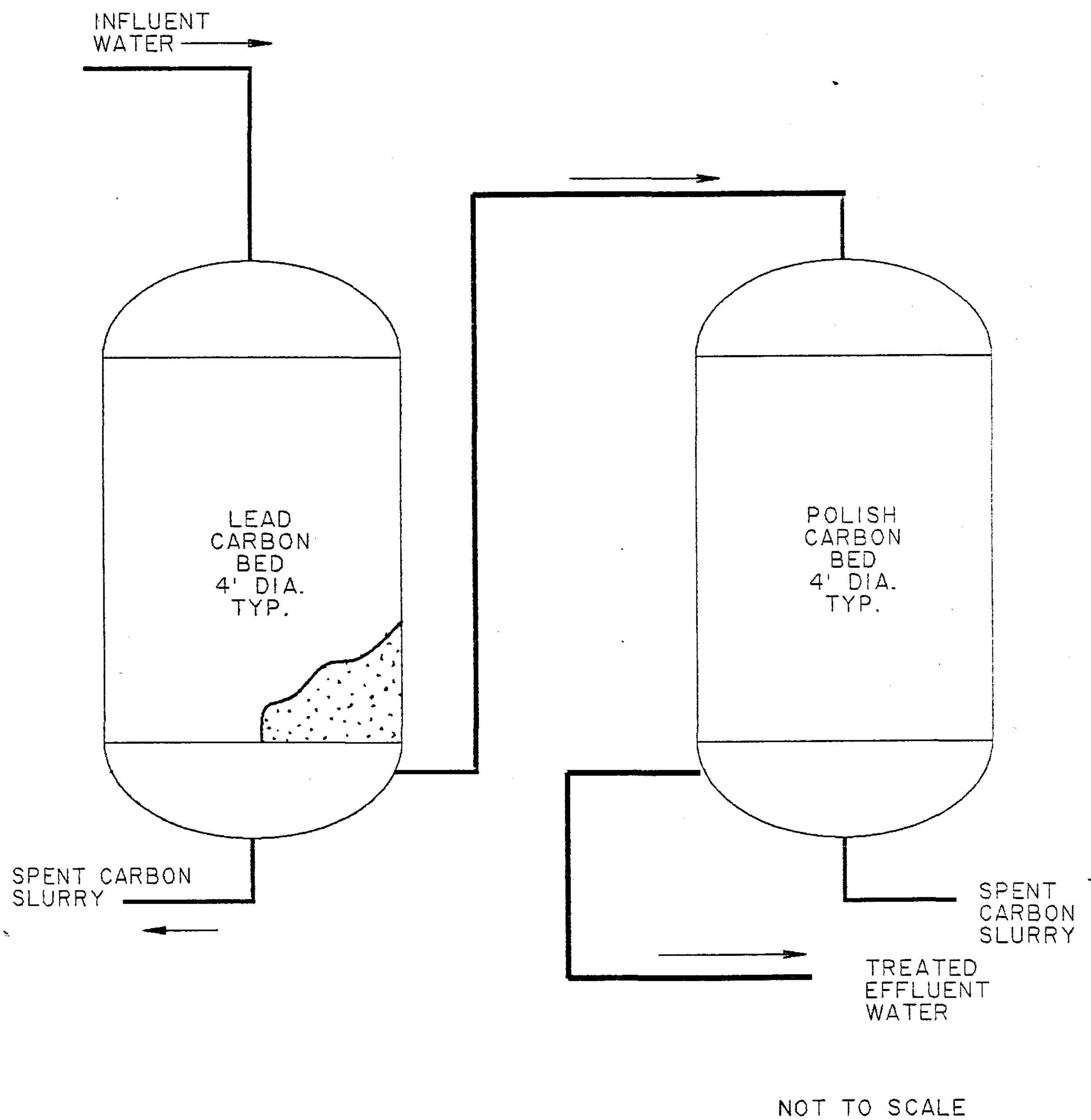
Compound	C_o* (ug/l)	Usage Rate (lb/1000 gal)	Breakthrough Order
Carbon Tetrachloride	ND		
1,1-Dichloroethane	2	0.8	3
1,1-Dichloroethylene	1,050		
Methylene Chloride	4	3.1	1
Tetrachloroethylene	350		
Toluene	1		
1,1,1-Trichloroethane	1,700	1.1	2
1,1,2-Trichloroethane	3		
Trichloroethylene	1,050		

* These values are concentrations for a water sample made of approximately 9 parts footing drain water and 1 part well #9-74 water.

capacities as evidenced by their low influent feed concentrations and rapid breakthrough. Because methylene chloride breaks through first, the estimated carbon usage rate is 3.1 lbs/1000 gals.

Two common granular activated carbon treatment processes are fixed beds and pulse beds systems. In a fixed bed system, the water flows through a vessel containing activated carbon until the carbon is spent. The carbon is then removed and replaced with regenerated or virgin carbon. The advantages of this process include a lower profile, less pressure needed at the inlet, and the system may operate with some suspended solids. Disadvantages include potentially higher capital costs and variations in the effluent concentrations. A pulse bed system passes water up through the vessel. Small amounts of spent carbon are removed from the bottom of the vessel at frequent intervals ("pulsing"), with the same amount of new carbon being added at the top. The advantages of this system include a consistent effluent quality and a small area requirement for the vessels. Disadvantages include not being able to treat water with suspended solids and generating carbon fines in the effluent, which will require filtration during each pulsing operation.

Carbon vessels may be operated individually or several may be combined into a series, parallel, or multiple series and parallel configuration. In a series system, the downstream vessels would collect breakthrough components while the carbon in the lead vessel approaches maximum adsorption capacity (see Figure 2-8). When the decision is made to change the carbon, the flow is diverted from the lead (first) vessel into the polish (second) vessel (which is now the lead vessel in the series). This ensures that the influent continues to be treated (no shutdown of the operation) while the carbon is changed in the original lead vessel. Once the original lead vessel has been filled with new carbon, this vessel is added as the last vessel of the series. When



R.SK.CARBON.ADSORPTION.UNIT

ISSUE	DESCRIPTION	DATE					CLASS	JOB NO.
A	ORIGINAL ISSUE	2/10/88	REJ	NDS			SDS	986124

BLDG

ROOM

CAT.

DESIGNED JAMES
DRAWN DESANTIS
CHECKED
APPROVED
RELEASE DATE 3-1-88

FIG 2-8
CARBON ADSORPTION TREATMENT UNIT

ROCKWELL INTERNATIONAL
ROCKY FLATS PLANT GOLDEN, COLORADO 80402-0464

SIZE		ISSUE	SHEET
A	38423-017	A	OF

COMPUTER GENERATED NO MANUAL CHANGES ALLOWED

flow rates exceed the capacity of a single vessel, a parallel configuration is used to reduce the hydraulic loading. Attaching additional vessels to the ones in parallel (series systems in parallel) provides backup for contaminant capture in the event of breakthrough for the primary (lead) vessels.

When designing a granular activated carbon system, certain parameters should be considered, including contact time and hydraulic loading.

Contact time is the time that a volume of water is exposed to carbon as it flows through the carbon bed. Factors that determine the necessary contact time include the amount of pores and the surface area on the carbon, the selective nature of adsorption (some organic molecules are more readily adsorbed than others), and the concentration of the adsorbates in solution. Contact times should be calculated from data collected during the column testing. Typical contact times range from 15 to 40 minutes.

Hydraulic loading is the flow of water per cross-sectional surface area (gpm/ft^2) of the carbon vessel. Flows in the range of 2 to 10 gpm/ft^2 are common (USEPA, 1971). Head loss over the length of the vessel is directly related to hydraulic loading. If the head loss is high, pumps for pressuring the system may be needed. Generally, a hydraulic loading of 4 gpm/ft^2 is the limit for gravity flow.

A representative carbon adsorption unit is a two-vessel, in series, system. The vessels have a cross-sectional area of approximately 12 square feet, stand approximately 10 feet tall, and contain approximately 2000 pounds of carbon each. When the carbon in the lead vessel was spent, the carbon is removed and replaced with regenerated carbon. The flow is then reversed so this vessel would now act as the backup. The capital cost for this system has been estimated at $50,000.

Carbon may be either regenerated or purchased with subsequent disposal. The cost of regenerated carbon is approximately $0.90/pound. If the carbon is sent for disposal, the costs would be approximately $1.10/pound including shipping. Shipping costs for regeneration are estimated to be $1.25/pound.

Based on the ACT, the rate of carbon use is estimated to be 3.1 pounds/1000 gallons. This translates into 45 pounds of carbon used per day (assuming 24-hour operation at 10 gpm), and would require the removal and substitution of new carbon in the vessel approximately every 45 days (assuming 2000 pounds of carbon per vessel). Based on this carbon usage rate, the cost of carbon would be approximately $40/day (or $15,000/yr excluding shipping cost).

Because activated carbon treatment is a technically reliable and cost effective technology, it has been retained for detailed alternative evaluation (Section 4).

2.2.7 Summary of Technology Screening

The screening of the remedial action technologies is summarized in Table 2-7. The technologies that have been retained after screening for development into potential remedial alternatives are listed below:

- No remedial action - monitoring only;
- Off-site RCRA landfill;
- Well Arrays;
- Subsurface drains;
- Soil - bentonite slurry walls;
- Multi-layer cap;
- Grading and vegetation;
- Surface water diversion;
- In situ Immobilization (grouting);
- Soil flushing;
- UV/Peroxide Water Treatment;
- Air Stripping Water Treatment; and
- Activated Carbon Adsorption Water Treatment.

TABLE 2-7

SUMMARY OF TECHNOLOGY SCREENING

SCREENED TECHNOLOGY	RETAINED FOR ALTERNATIVE DEVELOPMENT	TECHNICAL CONSIDERATIONS	PUBLIC HEALTH, ENVIRONMENTAL, AND INSTITUTIONAL, AND COST CONSIDERATIONS
No Action			
Monitoring	Yes	This technology includes ground water and surface water monitoring only.	Remedial action would be implemented if contaminant migration results in exceeding public health and environmental criteria near, but within the facility boundary to intercept contaminants prior to impacting downgradient receptors. CERCLA guidance requires consideration of this alternative.
Complete or Partial Removal			
Off-Site Landfill	Yes	Dust generation and contaminant volitilization will have to be controlled, as will drainage.	This technology will accelerate ground-water remediation. DOT regulations regarding hazardous waste transport must be addressed. Meets NCP requirement to evaluate off-site disposal at a RCRA facility.
Ground-Water Collection and Containment Controls			
Well Arrays	Yes	Pumping is most effective in materials with relatively high intergranular hydraulic conductivities. Injection wells require regular maintenance and are subject to clogging.	A system of injection and/or ejection wells can control and remove contaminant plumes or control leachate generation by lowering the water table, thus minimizing off-site exposure.
Subsurface Drains	Yes	Effective in low or variable hydraulic conductivity materials at relatively shallow depths.	As with wells, drains are effective at controlling plume migration and minimizing off-site exposure.

TABLE 2-7
(CONTINUED)
SUMMARY OF TECHNOLOGY SCREENING

SCREENED TECHNOLOGY	RETAINED FOR ALTERNATIVE DEVELOPMENT	TECHNICAL CONSIDERATIONS	PUBLIC HEALTH, ENVIRONMENTAL, AND INSTITUTIONAL, AND COST CONSIDERATIONS
Ground-Water Collection and Containment Controls (Continued)			
Subsurface Barriers			
1. Soil-Bentonite Slurry Walls	Yes	Soil-bentonite walls have the lowest permeabilities; they also have the highest compressibility. Hydraulic conductivity is approximately $1x10^{-8}$ cm/s.	Soil-bentonite walls offer the lowest installation costs and a wide range of chemical compatibilities.
2. Cement-Bentonite Slurry Walls	No	Cement-bentonite walls have a larger hydraulic conductivity than soil-bentonite slurry walls. Cement has a narrow range of chemical compatibilities. Soil-bentonite wall will be more effective.	
3. Diaphragm Walls	No	Diaphragm walls are utilized in situations where large loads must be supported. Not applicable to the 881 Hillside.	
4. Grout Curtains	No	Grout curtains are generally incapable of attaining truly low hydraulic conductivities.	Grout curtains are more expensive and less reliable than slurry walls.
5. Sheet Piling	No	Sheet piling is subject to corrosion and other damaging effects that limit the life of the walls. Alluvial sands at the 881 Hillside may cause unacceptable separation of the interlocks.	
6. Bottom Sealing	No	The claystone of the Arapahoe Formation underlying the 881 Hillside is not known to have subcropping sandstones in areas of organic contamination. Therefore bottom sealing is not required.	

TABLE 2-7
(CONTINUED)
SUMMARY OF TECHNOLOGY SCREENING

SCREENED TECHNOLOGY	RETAINED FOR ALTERNATIVE DEVELOPMENT	TECHNICAL CONSIDERATIONS	PUBLIC HEALTH, ENVIRONMENTAL, AND INSTITUTIONAL, AND COST CONSIDERATIONS
Infiltration Controls			
Capping:			
1. Single Layer Cap	No	The most effective single layer caps are composed of portland cement or asphalt concrete. Single layer caps are only acceptable as temporary covers.	
2. Multi-Layer Cap	Yes	Multi-layer caps generally conform to EPA guidance under RCRA which recommends a three-layer system consisting of an upper vegetative layer, underlain by a drainage layer over a low permeability layer.	A multi-layer cap is more costly than a single layer cap, but it provides for a better control infiltration and subsequent contaminant leaching.
Grading	Yes	Grading, reshaping of the ground surface, is used to reduce ponding, reduce run-off velocities, and prepare the soil for revegetation.	Grading reduces infiltration and, thus, contaminant concentrations in the ground water.
Surface Water Diversion	Yes	Surface water diversions, dikes, and berms, are used to provide protection of critical areas by intercepting storm run-off and diverting the flow to drainage ways.	Dikes and berms reduce surface water infiltration and subsequent leaching of contaminants into the ground water.
In Situ Treatment/Immobilization			
Grouting	Yes	A polymer grout appears feasible for the 881 Hillside Area.	Grouting of the soils will significantly reduce contaminant migration from the source, thus reducing any public exposure to contaminants off site.

TABLE 2-7
(CONTINUED)
SUMMARY OF TECHNOLOGY SCREENING

SCREENED TECHNOLOGY	RETAINED FOR ALTERNATIVE DEVELOPMENT	TECHNICAL CONSIDERATIONS	PUBLIC HEALTH, ENVIRONMENTAL, AND INSTITUTIONAL, AND COST CONSIDERATIONS
In Situ Treatment/Immobilization (Continued)			
Vitrification	No	In situ vitrification is not commercially available.	
Soil Flushing	Yes	In situ soil flushing is potentially applicable to the 881 Hillside soils. Use of water as the flushing fluid may have limited effectiveness.	In situ soil flushing may expedite the remediation of the 881 Hillside soils, and thus reduce any possible public exposure to contaminants off site.
In Situ Aeration	No	This process is potentially applicable to sandy soils containing VOCs. Soil conditions dictate the efficiency of the system. Resulting vapors can be collected and treated to meet appropriate air emission standards. Complete remediation may be limited by specific soil characteristics of the 881 Hillside Area.	
Biodegradation	No	This process is potentially applicable as both a soil and ground-water treatment. Development of the process for the site specific characteristics of the 881 Hillside would be required. There are inadequate data to support full implementation of this technology.	
Carbon Adsorption	No	This technology is potentially applicable to ground water containing VOCs. Water and soil characteristics may limit the efficiency of an in situ carbon bed. Removal of the carbon bed upon remediation of the contaminated area will be required along with appropriate treatment or disposal.	

TABLE 2-7
(CONTINUED)
SUMMARY OF TECHNOLOGY SCREENING

SCREENED TECHNOLOGY	RETAINED FOR ALTERNATIVE DEVELOPMENT	TECHNICAL CONSIDERATIONS	PUBLIC HEALTH, ENVIRONMENTAL, AND INSTITUTIONAL, AND COST CONSIDERATIONS
Ground-Water Treatment			
Wet Air Oxidation	No	Due to the relatively low level of contaminants in the ground water, this system is not considered economically practical.	
Supercritical Water Oxidation	No	Due to the relatively low level of contaminants in the ground water, this system is not considered economically practical. Full-scale treatment operations are also not currently available.	
Reverse Osmosis	No	This technology is potentially applicable to VOC contaminated ground water. Possible contaminant reaction and deterioration of a selected membrane must be evaluated. This system will result in a concentrated solution that will require treatment or disposal. Due to the low level of contaminants in the ground water, this process is not cost effective.	
Biological Treatment:			
1. Aerobic	No	The system is applicable to ground water containing low levels of VOCs. Consistent, low levels of VOCs are required to avoid shock loading of the organisms. A sludge will be formed which will require dewatering and disposal.	More conventional methods of ground-water treatment are available which have been proven effective and more cost efficient.

TABLE 2-7
(CONTINUED)
SUMMARY OF TECHNOLOGY SCREENING

SCREENED TECHNOLOGY	RETAINED FOR ALTERNATIVE DEVELOPMENT	TECHNICAL CONSIDERATIONS	PUBLIC HEALTH, ENVIRONMENTAL, AND INSTITUTIONAL, AND COST CONSIDERATIONS
Ground-Water Treatment (Continued)			
2. Anaerobic	No	The system is applicable to ground water containing moderate levels of VOCs. Consistent, moderate levels of VOCs are required to avoid shock loading of the organisms. A sludge will be formed which will require dewatering and disposal.	More conventional methods of ground-water treatment are available which have been proven effective and more cost efficient.
Ultraviolet (UV)/ Peroxide	Yes	The UV/peroxide process provides for the complete destruction of the VOCs.	This process appears cost effective.
Aeration Basin	No	The system is potentially applicable to ground-water containing VOCs. Collection and treatment of the off-gases must be considered.	Ground water can be treated with more efficient and cost effective treatment methods.
Air Stripping	Yes	Proven technology for the removal of VOCs from ground water. This process is advantageous for the removal of high volatility, low solubility compounds. Off-gas treatment may be required.	This process is cost effective for the removal of low level VOC contaminants from ground water. Treatment of off-gas streams may be required to meet air emission standards.
Activated Carbon Adsorption	Yes	Proven technology for the removal of VOCs from ground water. This treatment is highly effective for most organic compounds and for variable flow rates. Spent carbon will require disposal or regeneration.	This technology is a highly regarded ground-water treatment method. Costs of the process depend upon actual carbon usage and the method of carbon regeneration or disposal.

With the exception of the water treatment technologies, the technologies listed above will be combined in the development of the alternatives. The remedial action alternatives are formulated to address the environmental issues and the contaminant pathways related to the site and to meet the alternative screening criteria and the remedial action objectives. The three water treatment technologies are subjected to a detailed evaluation in Section 4 to determine the cost effective reliable treatment system for inclusion with the alternatives requiring water treatment.

2.3 REFERENCES

Cheremisinoff, Paul N. and Fred Ellerbusch. Carbon Adsorption Handbook. Ann Arbor Science Publishers, Inc., Ann Arbor, Michigan, 1980.

Duall Industry, Owosso, Michigan. Budget Proposal, January 1988.

Ellis, W.D., J.K. Payne, A.M. Tafuri, and F.J. Freestone, 1984. "The Development of Chemical Countermeasures for Hazardous Waste Contaminated Soil", in 1984 Hazardous Material Spills Conference, Nashville, Tennessee.

Faust, Samuel D. and Osman M. Aly. Chemistry of Water Treatment. Butterworth Publishers, Woburn, Massachusetts, 1983; page 188.

Hassler, John W. Purification with Activated Carbon: Industrial, Commercial, Environmental. Chemical Publishing Co., Inc., New York, New York, 1974; pages 206-212.

Knox, R.C., et al., 1984. State-of-the-Art of Aquifer Restoration. EPA/600/2-84/182B, Volume 2, Appendices A to G, Final Report.

Trost, P.B., MTA Remedial Resources, Inc., August 1987. Personal communication, plus In Situ Carbon Adsorption, an executive summary.

USEPA, 1981. Treatability Manual Volume I: Treatability Data. Office of Research and Development, EPA-600/2-82/001a.

USEPA, 1984. Aeration to Remove Volatile Organic Compounds from Ground Water, an Interim Report to the Office of Drinking Water; EPA/600/2-86/024, March 1984.

USEPA, 1985. Handbook: Remedial Action at Waste Disposal Sites (Revised). EPA/625/6-85/006, Hazardous Waste Engineering Research Laboratory, U.S. Environmental Protection Agency.

USEPA, 1986b. Mobile Treatment Technologies for Superfund Wastes, prepared by Camp Dresser & McKee, Inc., for the Office of Solid Waste and Emergency Response, EPA Contract Number 68-01-7053; Linda Galer, Project Officer, 1986.

USEPA, 1986c. Systems to Accelerate In Situ Stabilization of Waste Deposits. Hazardous Waste Engineering Research Laboratory, EPA Contract Number 68-03-3113, Task 37-2, W. Grube, Project Officer.

SECTION 3

INITIAL SCREENING OF REMEDIAL ALTERNATIVES

3.1 ALTERNATIVE DEVELOPMENT AND SCREENING PROCESS

Remedial action alternatives have been developed and screened for the 881 Hillside using the process described below.

1. Technologies retained after screening (Table 2-7) were combined that are complementary and interrelated, e.g., capping, site grading and surface water diversion.

2. Alternatives were then developed using the individual and grouped retained technologies that address the site issues and control contaminant pathways (Table 1-1). The specific objectives are to:

   - Contain, reduce, and/or eliminate contaminants that are possible sources of exposure to potential receptors;

   - Reduce or eliminate exposure of potential receptors to site contaminants by blocking migration pathways that lead to possible exposure; and

   - Develop remedial actions that are technically feasible, acceptable to the public, and cost effective.

   Not all alternatives will completely meet the objectives or be equally effective in addressing the site issues and controlling contaminant pathways.

3. The NCP requires that at least one alternative be evaluated in each of the following categories.

   - No action (can include monitoring).

   - Alternatives that meet the CERCLA goals of preventing or minimizing present or future migration of hazardous substances and protection of public health and the environment, but do not attain all of the applicable or relevant and appropriate requirements (ARARs).

   - Alternatives that meet the CERCLA goals and attain all ARARs.

   - Alternatives that exceed all ARARs.

- o Alternatives involving off-site storage, destruction, treatment, or secure disposal of hazardous substances at a facility approved under the Resource Conservation and Recovery Act (RCRA). Such a facility must also be in compliance with all other applicable EPA standards.

4. The NCP specifies that remedial alternatives, besides satisfying each of the categories, should be classified either as source control [40 CFR 300.68(e)(2)] of off-site (management of migration) remedial actions [40 CFR 300.68e(3)]. Source control remedial actions address situations in which hazardous substances remain at or near the areas where they were originally located, and are not adequately contained to prevent migration into the environment. Management of migration remedial actions address situations in which the hazardous substances have largely migrated from their original locations. Alternatives developed may fall solely in either classification or may involve a combination of source control and management of migration measures. With respect to the 881 Hillside, all remedial action alternatives are under the source control classification because hazardous substances remain near their source. These source control measures adequately address the site issues and control contaminant pathways.

5. SARA further requires that treatment alternatives be developed that consider:

   - o Elimination of long term site management;
   - o Reduction of waste toxicity, mobility, or volume;
   - o Waste containment with little or no treatment;
   - o Use of innovative technologies.

6. Three broad considerations, consistent with the National Contingency Plan, are utilized as the basis for the preliminary screening of developed alternatives:

   - o <u>Cost</u> - The cost of implementing the remedial action will be considered including operation and maintenance costs. An alternative whose cost far exceeds that of others being evaluated will likely be eliminated.
   - o <u>Acceptable Engineering Practices</u> - Alternatives which are not feasible for the location and conditions are not applicable to the problem and do not provide a proven and reliable means of addressing the problem will be eliminated.
   - o <u>Effectiveness</u> - Alternatives which do not effectively contribute to the protection of public health, welfare, and the environment will be eliminated. Alternatives posing significant adverse

environmental effects and only limited benefits will also be excluded from further consideration.

In the screening process, alternatives will be eliminated that do not provide adequate protection of public health, welfare, and the environment, and those that are much more costly than others without providing significantly greater protection. When alternatives are eliminated from further consideration, the feasibility study documents the rationale for excluding each alternative.

3.2 REMEDIAL ALTERNATIVES FOR THE 881 HILLSIDE AREA

The remedial action alternatives for the 881 Hillside are:

1. No action;

2. Collection of ground water using a line of downgradient wells and a source well at SWMU 119.1, collection of footing drain flow from SWMU 107, treatment of collected water in a new treatment plant and reinjection of treated water downgradient of the 881 Hillside Area in the Valley Fill Alluvium of the Woman Creek drainage;

3. Collection of ground water using a french drain and a source well at SWMU 119.1, collection of footing drain flow from SWMU 107, treatment of collected water in a new treatment plant and reinjection of treated water downgradient of the 881 Hillside Area in the Valley Fill Alluvium of the Woman Creek drainage;

4. Collection of ground water using a french drain and a source well at SWMU 119.1, collection of footing drain flow from SWMU 107, treatment of collected water in a new treatment plant, discharge of treated water to the surface, and in-situ treatment of soils using soil flushing;

5. Total encapsulation of source areas using a multi-layer cap and slurry wall with control of gradients by pumping an internal sump (dewatering fluids to be treated at an existing treatment plant);

6. Immobilization of contaminants using a chemical grout;

7. Pump a source well at SWMU 119.1, collect footing drain flow from SWMU 103, treat collected water at a new treatment plant, and reinjection of treated water downgradient of the 881 Hillside Area in the Valley Fill Alluvium of the Woman Creek drainage; and

8. Collection of ground water using a french drain and a source well at SWMU 119.1, collection of footing drain flow from SWMU 107, treatment of collected water in a new treatment plant, reinjection of treated water downgradient of the site, and partial removal of soils to a RCRA permitted disposal facility.

Based on the screening of water treatment technologies in Section 2, carbon adsorption air stripping, and UV peroxide treatment are all cost effective candidate treatment processes effective for the removal of the volatile organics from the ground water at the 881 Hillside. These treatment technologies are subjected to a detailed evaluation in Section 4 in order to select the preferred process for water treatment associated with the above alternatives.

3.3 ALTERNATIVE SCREENING

3.3.1 No Action

3.3.1.1 Description

Under the no-action alternative, no remedial activities will be performed; however, ground-water and surface water conditions in the area will be monitored. Ground-water and surface water conditions will be monitored as follows.

SWMU 107

1) wells 53-87, 2-87, 3-87BR, 59-86BR, 8-87BR, 69-86.

2) footing drain discharge and outfall to the Interceptor Ditch.

SWMU 119.1

1) wells 43-87, 5-87BR, 4-87, 49-87, 6-87, 47-87, 48-87, 55-87, 64-86.

The locations of these monitoring stations are shown on Figures 1-4. Site features are shown on Figure 3-1.

Samples will be collected on a semi-annual basis for a period of thirty years or until volatile organic compounds (VOCs) are no longer detected in the wells or drain discharges. The samples will be collected using stainless steel or teflon pumps or bailers. The samples will be analyzed for HSL volatiles and the following indicator parameters: pH, conductivity, temperature and total dissolved solids (TDS). In addition, the footing drain flow will be measured.

3.3.1.2 Effectiveness

There is currently limited environmental impact from SWMU 107 and little potential for hazard to the public health. Although there are volatile organic compounds in the soil and ground water in the vicinity of SWMU 107, downgradient ground-water quality is not degraded, apparently because ground-water flow in the area is collected by the drains. The effectiveness of the existing drains in collecting contaminated ground water is evidenced by the presence of VOCs in soils and ground water near the drain and in the discharge from the drain, but the absence of VOCs in soil and ground-water samples downgradient. VOCs in the discharge from the drain enter the skimming pond which subsequently discharges to the South Interceptor Ditch. There is a significant reduction in VOCs in the pond, apparently due to volatilization. Dilution/volatilization further reduces VOC concentrations to non-detectable levels in the South Interceptor Ditch.

There is also no imminent hazard to the public health from SWMU 119.1. Although there are VOCs in the ground water near SWMU 119.1, it appears that the VOCs have not migrated to the Valley Fill Alluvium of Woman Creek or into bedrock sandstones of the Arapahoe Formation. This apparently is the result of limited ground-water flow in the area, coupled with attenuative processes. VOCs have also not been detected in the surface waters of the South Interceptor Ditch and Woman Creek.

The monitoring program will not improve site conditions, minimize the generation of contaminants, or mitigate any potential long term risks. Instead, the monitoring program serves as an early warning system to detect changes in contaminant migration. In the event contaminated ground water migrates beyond its present localized area (indicating greater potential for hazard to the public health), a remedial action plan will be developed and implemented to safeguard potential receptors.

3.3.1.3 Acceptable Engineering Practices

This criterion is not applicable to the no action alternative.

3.3.1.4 Cost Considerations

There is no capital cost associated with this alternative because the monitoring wells have already been installed. The present worth of the monitoring costs is $622,000 using a 10% discount rate over thirty years. Costing information is presented in Table 3-1.

3.3.1.5 Conclusion

This alternative has been retained for detailed evaluation in keeping with the guidelines of the NCP.

3.3.2 Alternative 2: Line of Wells with Treatment

3.3.2.1 Description

Alternative 2 consists of the interception of ground-water flow from the Hillside using a line of pumping wells. Water collected from the line of pumping wells, a source well at SWMU 119.1 (well 9-74), and the Building 881 footing drain flow will be treated in a new treatment plant (see Section 4.2). Effluent from the treatment plant will be reinjection of treated water downgradient of the 881 Hillside Area in the Valley Fill Alluvium of the Woman Creek drainage.

The pumping system will involve approximately 165 wells located on 10-foot centers along the line shown on Figure 3-2. It is estimated that the wells will average about twenty feet in depth and that the discharge from each well will begin at about 1 gpm but will fall rapidly. The estimated total production from the well system is approximately 2 gpm. In addition, a sump will be built to collect the flow from the Building 881 footing drain and well 9-74 will be pumped. Total steady flow to the treatment plant is estimated to be 8 gpm.

The wells will be cased with 4-inch diameter PVC casing and pumped with small submersible pumps. The performance of each pump (time of operation, flow rate, and water level in the well) will be monitored on a monthly basis. The riser pipe from each well will join a common main for delivery to the treatment plant. All piping will be buried a minimum of four feet below ground to minimize potential freezing problems.

TABLE 3-1

ALTERNATIVE 1 (NO ACTION) ESTIMATED COSTS

	ITEM	UNIT(S)	UNIT COST	TOTAL
CAPITAL COSTS				
	None			$ 0
OPERATING COSTS				
	GW Samples	15	$ 2,000	$ 30,000
	SW Samples	2	$ 1,500	$ 3,000
				$ 33,000
ANNUAL COST				
	Twice a year for 30 years		$	66,000
PRESENT WORTH				$622,000

The performance of the system will be monitored by sampling wells and surface waters in the area. For conceptual design level costing purposes, it has been assumed that the monitoring program will be the same as described in the no-action alternative but will also include monthly monitoring of the influent and effluent of the treatment plant for HSL volatiles.

3.3.2.2 Effectiveness

Collection and treatment of all ground water leaving the Hillside will contain and remove the volatile organics currently being released to this medium. However, because of subsurface heterogeneities, complete cutoff of ground-water flow by overlapping cones of depression from the dewatering wells is not absolutely assured. Ground water at the site should eventually meet or exceed chemical constituent ARARs and the effluent from the treatment plant will meet or exceed these ARARs. Therefore, this alternative meets or exceeds ARARs.

3.3.2.3 Acceptable Engineering Practice

This alternative involves only proven technologies; dewatering wells have been used for control of ground-water flow for many years.

3.3.2.4 Cost Considerations

The capital cost of this alternative is approximately $545,000. The present worth, considering monitoring and operation and maintenance costs, is $2,796,000 using a 10% discount rate over thirty years. Costing information is presented in Table 3-2.

TABLE 3-2

ALTERNATIVE 2 (WELLS)
ESTIMATED COSTS

	ITEM	UNIT(S)	UNIT COST	TOTAL
CAPITAL COSTS				
Treatment Plant				$ 215,000
Well System:				
	Wells	165	$ 1,000	165,000
	Pumps/Pipes	165	$ 1,000	165,000
	TOTAL:			$ 545,000
OPERATING COSTS				
Treatment Plant O&M				$ 81,000
Well System:				
	Wells	165	$10/month	$ 19,800
Environmental Monitoring:				
	GW Samples	15	$ 2,000	
	SW Samples	2	$ 1,500	
	Twice a year for 30 years			$ 66,000
Treatment System Monitoring:				
	4 Samples/ Month	48	$ 1,500	$ 72,000
	TOTAL ANNUAL OPERATING COSTS:			$ 238,800
PRESENT WORTH				$ 2,796,000

3.3.2.5 Conclusion

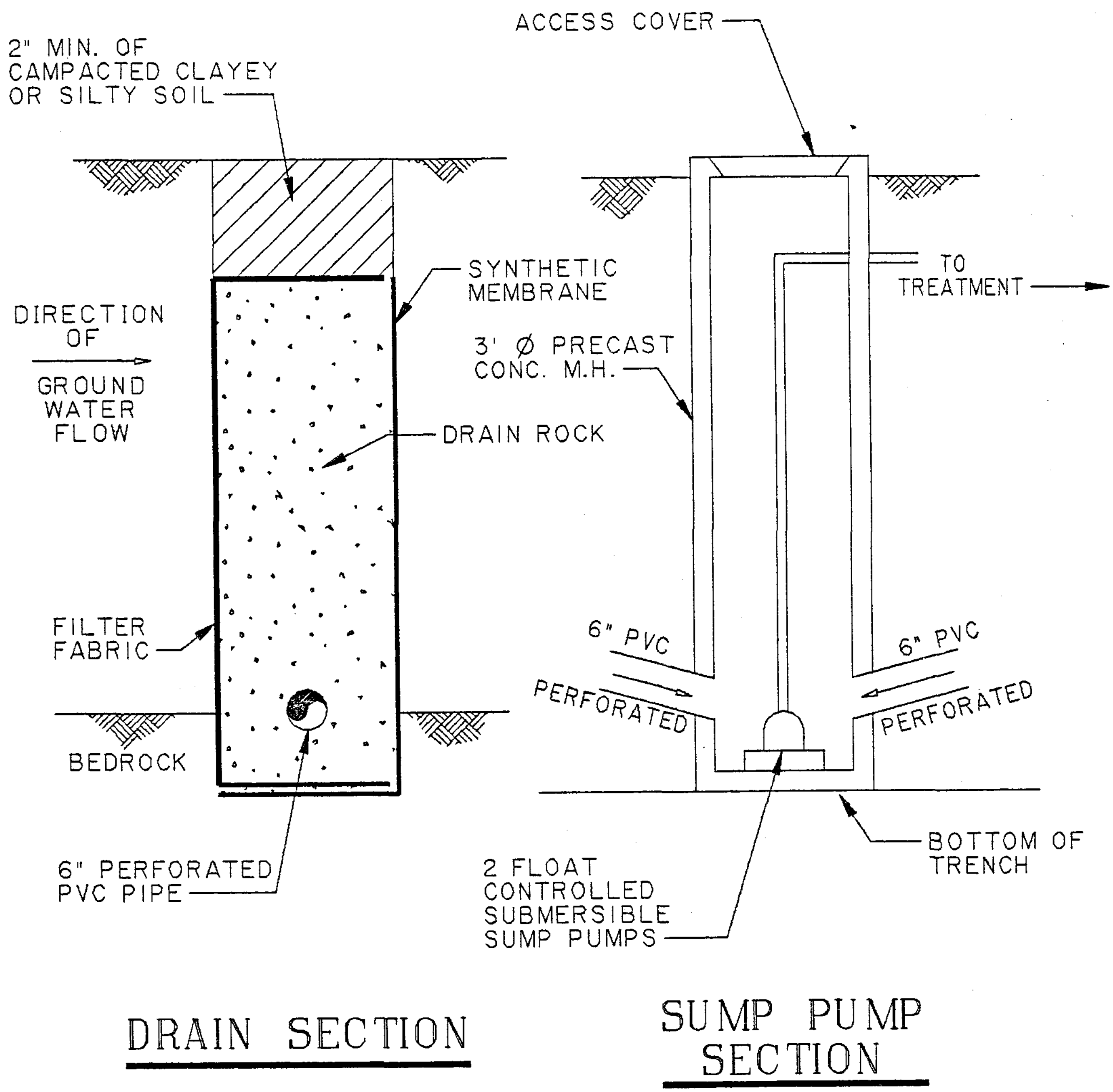
This alternative has not been retained for further evaluation because the well construction cost exceeds that of a French drain and because the well array is not expected to perform as effectively as a French drain (complete cutoff of ground-water flow by wells cannot be assured).

3.3.3 Alternative 3: French Drain

3.3.3.1 Description

This alternative involves construction of a french (trench) drain at the location shown on Figure 3-3. The downstream face of the trench will be covered with a synthetic membrane to limit flow from the clean side of the trench (Figure 3-4). The inclusion of the downstream synthetic membrane coupled with the continuity of the drain is expected to provide positive cutoff of the ground water. Water collected from the drain plus a source well at SWMU 119.1 (well 9-74) will be treated in a new treatment plant (see Section 4.2). In addition, a sump will be built to collect the flow from the Building 881 footing drain. Sump pumps will be used to move the footing drain flow to the treatment plant in a separate piping system. Effluent from the treatment plant will be reinjection of treated water downgradient of the 881 Hillside Area in the Valley Fill Alluvium of the Woman Creek drainage.

The conceptual design of this alternative involves a drain approximately 15 feet deep (in order to fully penetrate the soils) and 1,650 feet long. A drainage pipe (PVC) inside the drain will flow under gravity to a single central collection sump (3 foot diameter corrugated metal pipe). A submersible sump pump will be used to



NOT TO SCALE

R.SK.FRENCH.DRAIN.SECTION

ISSUE	DESCRIPTION	DATE					CLASS	JOB NO.
A	ORIGINAL ISSUE	2-10-88	REJ	NDS			SDS	986124

DESIGNED JAMES	FIG 3-4 FRENCH DRAIN SECTION	ROCKWELL INTERNATIONAL	BLDG.
DRAWN DESANTIS		ROCKY FLATS PLANT GOLDEN, COLORADO 80402-0464	ROOM
CHECKED		SIZE: A / 38423-019 / ISSUE: A / SHEET OF	CAT.
APPROVED			
RELEASE DATE 3-1-88			

COMPUTER GENERATED NO MANUAL CHANGES ALLOWED

deliver the water from the drain to the treatment plant. In order to expedite contaminant removal from SWMU 119.1, well 9-74 will also be pumped and routed to the treatment plant in separate plumbing.

Flow from the trench could be on the order of 100 gpm initially, but is expected to drop to less than 5 gpm within a few days. Steady flow from the trench could be as low as 2 gpm.

The performance of the system will be monitored by sampling wells and surface waters in the area. For conceptual design level costing purposes, it has been assumed that the monitoring program will be the same as described for Alternative 2.

3.3.3.2 Effectiveness

Collection and treatment of the discharge from the french drain will remove all of the volatile organics migrating in the ground water from the 881 Hillside. The drain will fully penetrate the soils and will provide a positive cutoff of colluvial ground-water flow. As with Alternative 2, it is concluded that this alternative will meet or exceed ARARs.

The risk assessment concludes (Appendix 1) that contamination levels of soils in the most contaminated areas of the 881 Hillside do not pose an unacceptable public health risk. The drain location is such that contaminated soils are not expected to be encountered, and if encountered, are thus not expected to pose an unacceptable risk to the public health. Therefore, these soils will be returned to the excavation and excess material evenly spread over the ground in the vicinity of the drain.

3.3.3.3 Acceptable Engineering Practice

This alternative uses only proven technologies. It is expected to be highly effective in containing contaminant migration.

3.3.3.4 Cost Considerations

The capital cost of this alternative is approximately $296,000. The present worth, considering monitoring and operation and maintenance costs, is $2,364,000 using a 10% discount rate over thirty years. Costing information is presented in Table 3-3.

3.3.3.5 Conclusion

This alternative has been retained for further evaluation because it is expected to be highly effective in containing contamination from the Hillside area. In addition, it will destroy the contaminants during ground-water treatment. Therefore, the alternative exceeds all ARARs and meets the intent of SARA.

3.3.4 <u>Alternative 4: French Drain with Soil Flushing</u>

3.3.4.1 Description

This alternative involves containment and treatment of ground water using the technologies described in Alternative 3; however, soil flushing is added to hasten volatile removal from the soils and ground water. A french drain with a downstream synthetic membrane cutoff (see Alternative 3) will be used to contain and collect the

TABLE 3-3

ALTERNATIVE 3 (FRENCH DRAIN) ESTIMATED COSTS

	ITEM	UNIT(S)	UNIT COST	TOTAL
CAPITAL COSTS				
Treatment Plant				$ 215,000
French Drain:				
	Excavation	3,667 yds	$2.25	8,250
	Dewatering	10 days	$400	4,000
	Drain Pipe (6" PVC)	1,650 ft.	$3,64	6,006
	Filter Fabric	2,750 yd^2	$2.00	5,500
	Synthetic Membrane	2,750 yd^2	$2.00	5,500
	Drain Rock	3,667 yds	$10	36,667
	Sump: Precast Concrete	L.S.	$2,000	2,000
	Pump and Controllers	L.S.	$2,000	2,000
	Piping	L.S.	$2,000	2,000
Source Well:				
	Pump and Piping	L.S.	$1,000	1,000
Sump at Footing Drain:				
	Excavation	L.S.	$2,000	2,000
	Sump: Precast Concrete 16' Deep)	L.S.	$2,000	2,000
	Pump and Controllers	L.S.	$2,000	2,000
	Piping	L.S.	$2,000	2,000
	TOTAL:			$ 295,983

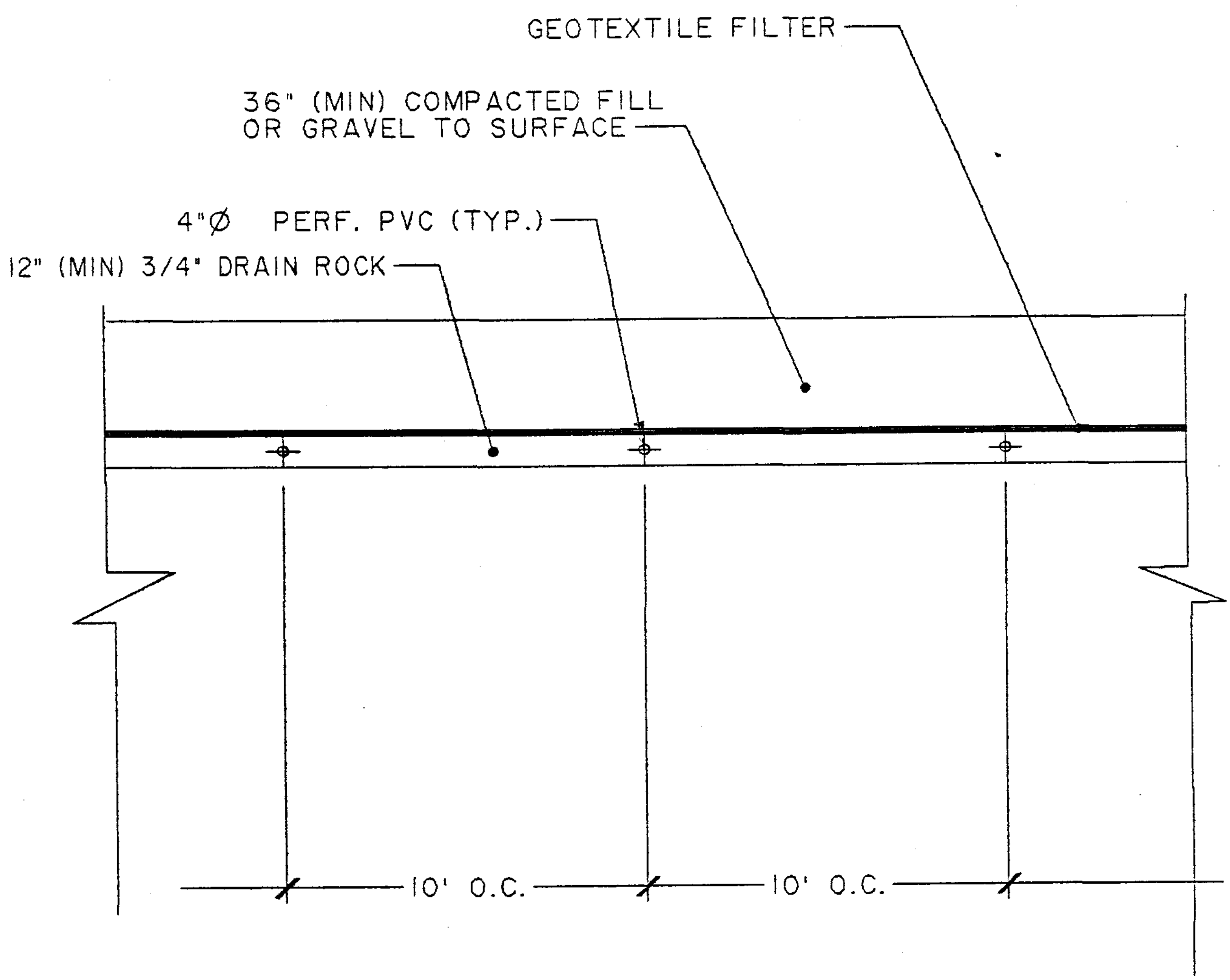
TABLE 3-3
(CONTINUED)
ALTERNATIVE 3 (FRENCH DRAIN)
ESTIMATED COSTS

	ITEM	UNIT(S)	UNIT COST	TOTAL
OPERATING COSTS				
Treatment Plant O&M:				$ 81,000
	Drain System	12 mos.	$10/mo	120
	Source Well	12 mos.	$10/mo	120
	103 Drain	12 mos.	$10/mo	120
Environmental Monitoring:	GW Samples	15	$2,000	
	SW Samples	2	$1,500	
	Twice a week for 30 years			$ 66,000
Treatment System Monitoring	4 Samples/ Month	48	$1,500	$ 72,000
	TOTAL ANNUAL OPERATING COSTS:			$ 219,360
PRESENT WORTH				$ 2,364,000

ground water. Water collected from the drain plus a source well at SWMU 119.1 (well 9-74) will be treated in a new treatment plant (see Section 4.2). In addition, the flow from the Building 881 footing drain will be treated in the treatment plant. Most of the effluent from the treatment plant will be reinjection of treated water downgradient of the 881 Hillside Area in the Valley Fill Alluvium of the Woman Creek drainage; however, a smaller amount (on the order of 1 gpm) will be flushed through the soils at SWMU 119.1 (Figure 3-5). The goal of the soil flushing at SWMU 119.1 is to flush VOCs from the soil grains and to provide additional hydraulic drive to displace contaminated ground water, thus shortening the time that treatment is required.

Soil flushing will be achieved by injection into a leach field. For conceptual design purposes it is assumed that the uphill area shown in Figure 3-5 will be cut and the downhill area filled to create a mildly sloping surface. Approximately one foot of drain rock will be placed over the surface, embedding six-inch perforated PVC pipe (see Figure 3-6). Water will be delivered to the leach field from the treatment plant via a dosing tank for uniform application. Using a saturated hydraulic conductivity of 1x10-6 cm/s for the clayey soil and a recharge area of 56,000 square feet, it is estimated that approximately 0.8 gpm can be introduced into the subsurface. Thus, approximately two years of flushing will be required before 10 pore volumes are flushed through the underlying soils (no winter operation).

The performance of the system will be monitored by sampling wells and surface waters in the area. For conceptual design level costing purposes, it has been assumed that the monitoring program will be the same as described Alternative 2.



SCALE: 1"= 5'

R.SK.INFILTRATION.GALLERY.SECTION

A	ORIGINAL ISSUE	2-10-88	REJ NDS	SDS	986124
ISSUE	DESCRIPTION	DATE		CLASS	JOB NO.

BLDG.

DESIGNED JAMES	FIG 3-6 INFILTRATION GALLERY SECTION	ROCKWELL INTERNATIONAL ROCKY FLATS PLANT GOLDEN,COLORADO 80402-0464
DRAWN DESANTIS		
CHECKED		SIZE: A — 38423-021 — ISSUE: A — SHEET OF
APPROVED		
RELEASE DATE 3-1-88		

ROOM

CAT.

COMPUTER GENERATED NO MANUAL CHANGES ALLOWED

3.3.4.2 Effectiveness

Collection and treatment of the discharge from the french drain will remove all of the volatile organics migrating in the ground water from the 881 Hillside. It is concluded that this alternative will meet or exceed ARARs without consideration of the effectiveness of soil flushing. Soil flushing is expected to reduce VOC concentrations in the soil and shorten the time that treatment is required, both because of displacement of contaminated ground water and removal of a potential source of VOCs. Incorporation of soil flushing (an innovative technology) meets the intent of SARA.

3.3.4.3 Acceptable Engineering Practice

This alternative uses proven technology for control of ground-water flow but an innovative technology for in-situ soil treatment. Soil flushing has been used with apparent success at the Goose Farm site in New Jersey and has shown promise in repeated laboratory tests. Based on a brief description in EPA (1984), it appears that total organic carbon in soils at the Goose Farm site was reduced from 30 to approximately 2 milligrams per gram by in-situ flushing of the soils with about 7 pore volumes of water. Ellis et al. (1984) report 98 percent removal of chlorinated phenols by the passage of 3 pore volumes of water in a laboratory study; however, less soluble organics required the addition of a surfactant.

The success of soil flushing is controlled by the water solubility of the contaminants and their potential to be adsorbed onto the soil (described by the soil/water partition coefficient, but usually approximated with the octanol/water partition coefficient). Solubilities and octanol/water partition coefficients for the compounds of interest at the 881 Hillside are:

Compound	Water Solubility (mg/l)	Log of Octanol/Water Part. Coef.
1,2-DCA	8,700	1.48
t-1,2-DCE	6,300	1.48
1,1-DCE	5,000	1.48
CHCl3	9,600	1.97
1,1,1-TCA	4,400	2.17
1,1,2-TCA	4,420	2.17
TCE	1,100	2.29
CCl4	800	2.64
PCE	150	2.88

Although it is by no means universally accepted, EPA (1985) reports that compounds can generally be removed from soils by water flushing if the log of the octanol/water partition coefficient is about 3 or less. Thus, it appears that the compounds of interest at SWMU 119.1 are probably amenable to soil flushing.

3.3.4.4 Cost Considerations

The capital cost of this alternative is approximately $352,000. The present worth, considering monitoring and operation and maintenance costs, is $2,416,000 using a 10% discount rate over thirty years. Costing information is presented in Table 3-4.

3.3.4.5 Conclusion

Although this alternative will meet or exceed ARARs at a relatively low cost and uses an innovative technology, it has not been retained for detailed evaluation.

TABLE 3-4

ALTERNATIVE 4 (DRAIN WITH SOIL FLUSHING) ESTIMATED COSTS

	ITEM	UNIT(S)	UNIT COST	TOTAL
CAPITAL COSTS				
Treatment Plant				$ 215,000
French Drain:				$ 71,923
Leach Field:				
	Excavation	4,167 yds	$2.25	$ 9,375
	Drain Pipe (4" PVC)	1,250 ft	$3.64	$ 4,550
	Drain Rock	4,167 yds	$10	$ 41,667
Source Well:				
	Pump and Piping	L.S.	$1,000	$ 1,000
	Sump at Footing Drain	L.S.	$8,000	$ 8,000
	TOTAL CAPITAL COSTS:			$ 351,515
OPERATING COSTS				
Treatment Plant O&M:				$ 81,000
	Drain System	12 mos	$10/mo	120
	Source Well	12 mos	$10/mo	120
	103 Drain	12 mos	$10/mo	120
	Reinjection	12 mos	$20/mo	240
Environmental Monitoring:				
	GW Sampling	15	$2,000	
	SW Sampling	2	$1,500	
	Twice a year for 30 years			$ 66,000

TABLE 3-4
(CONTINUED)
ALTERNATIVE 4 (DRAIN WITH SOIL FLUSHING)
ESTIMATED COSTS

	ITEM	UNIT(S)	UNIT COST	TOTAL
Treatment System Monitoring				
	4 Samples/ Year	48	$1,500	$72,000
	TOTAL ANNUAL OPERATING COSTS:			$219,000
PRESENT WORTH				$2,416,000

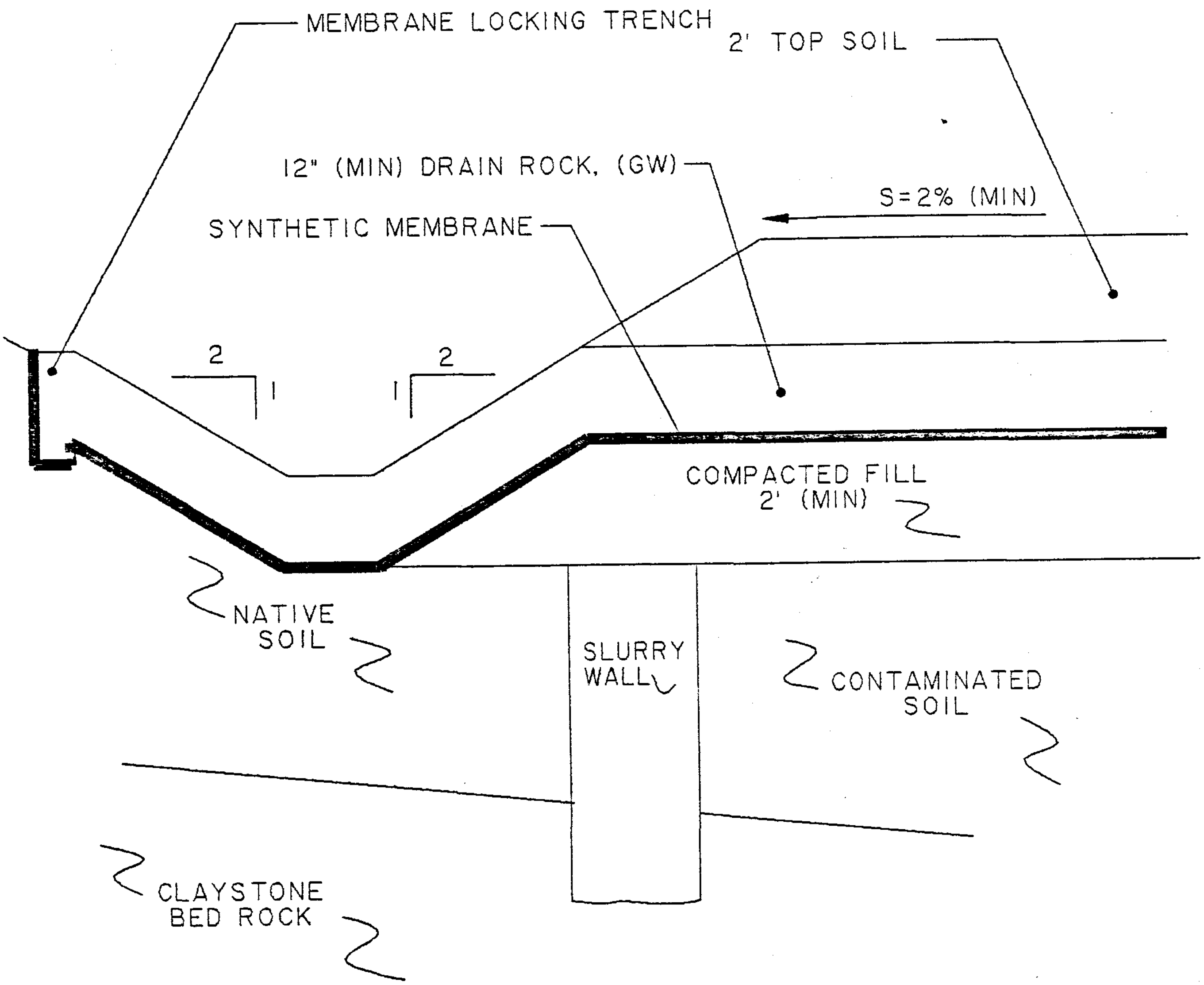
The practicality of soil flushing mildly soluble solvents must be documented by full scale field application before the added cost can be justified, when compared to a proven and equally effective alternative such as the french drain without flushing (Alternative 3).

3.3.5 Alternative 5: Total Encapsulation

3.3.5.1 Description

This alternative involves total encapsulation of the contaminant sources near SWMU 107 and within SWMU 119.1 using RCRA caps and slurry walls at the locations shown on Figure 3-7. Each area will be covered with a three-layer cap consisting of six-inches of vegetated topsoil, a minimum of six inches of drain rock, and a composite synthetic membrane/compacted soil cover of at least two-foot thickness (Figure 3-8). The surface of the cover will be sloped at a minimum of 2% to drain toward peripheral ditches. The peripheral ditches will discharge to the South Interceptor Trench. The cover at SWMU 107 is estimated to consist of approximately 6,000 square feet; the cover at SWMU 119.1, approximately 40,000 square feet. The covers will extend a minimum of five feet beyond the slurry walls.

Peripheral containment will be achieved by construction of soil-bentonite slurry walls to completely encircle the contaminated soils. The walls will be keyed into claystone bedrock, which is expected to provide bottom containment. The SWMU 107 slurry wall is estimated to be approximately 320 feet long and depths are anticipated to range from about 4 to 17 feet. It is estimated that the SWMU 119.1 wall will not exceed about twenty feet in depth (15 feet average) and that it will be approximately 1,000 feet long.



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R.SK.TOTAL.INCAPSULATION.SECTION

ISSUE	DESCRIPTION	DATE			SDS	986124
A	ORIGINAL ISSUE	2-10-88	R_{E_J}	N_{D_S}	CLASS	JOB NO.

DESIGNED JAMES	FIG 3-8 SITE 1, TOTAL ENCAPSULATION SECTION	ROCKWELL INTERNATIONAL ROCKY FLATS PLANT GOLDEN,COLORADO 80402-0464	BLDG.
DRAWN DESANTIS		SIZE / ISSUE / SHEET	ROOM
CHECKED		A	38423-023	A	OF	CAT.
APPROVED			
RELEASE DATE 3-1-88			

COMPUTER GENERATED NO MANUAL CHANGES ALLOWED

In addition, ground water inside the containment systems will be removed using internal sumps. This will result in hydraulic gradients toward the encapsulated soil and will reduce the potential for any releases. The small volume of water produced from the sumps will be stored in tanks on site to be transferred for treatment at the existing Rocky Flats Plant treatment facility.

The cap and perimeter ditches will be inspected on an annual basis and repaired as necessary. The ditches will be maintained in clean and properly graded condition so that collected runoff is rapidly removed from the area.

The performance of the system will be monitored by sampling wells and surface waters in the area. For conceptual design level costing purposes, it has been assumed that the monitoring program will be the same as described in the no-action alternative.

3.3.5.2 Effectiveness

Total encapsulation of the source of contamination is expected to eliminate release of volatile organics to ground water and surface water by use of a RCRA cap and slurry wall. This alternative is also in keeping with SARA in that it represents a waste containment alternative with little or no treatment.

A small volume of existing contaminated ground water outside (downgradient) of the encapsulation system will be allowed to flow toward the Valley Fill Alluvium; therefore, this alternative will not meet ARARs. Nevertheless, the compounds that enter the valley flow system are expected to be diluted and attenuated to non-detectable levels at the property boundary (Indiana Street) and therefore do not pose a hazard to the public or the environment.

3.3.5.3 Acceptable Engineering Practice

This alternative uses proven technologies to control the release and transport of VOCs.

3.3.5.4 Cost Considerations

The capital cost of this alternative is approximately $143,000. The present worth, considering monitoring and operation and maintenance costs, is $861,000 using a 10% discount rate over thirty years. Costing information is presented in Table 3-5.

3.3.5.5 Conclusion

Because this alternative meets RCRA closure requirements, involves nominal maintenance, and is cost effective, it has been retained for further evaluation.

3.3.6 Alternative 6: Immobilization

3.3.6.1 Description

Alternative 6 involves immobilization of the VOCs in the soils using grout (Figure 3-9). Grout will halt the flow of ground water through the source areas by decreasing the hydraulic conductivity and will also seal the VOCs in place. Because of the relatively high hydraulic conductivity of the soils in the vicinity of SWMU 107, it is anticipated that water flow can be practically eliminated using a polymer grout. It is anticipated that injection holes on approximately 10 foot centers will be required given the low injection pressures

TABLE 3-5

ALTERNATIVE 5 (ENCAPSULATION) ESTIMATED COSTS

	ITEM	UNIT(S)	UNIT COST	TOTAL
CAPITAL COSTS				
Cover				
	Site Prep	L.S.	$ 5,000	$ 5,000
	Compacted Soil: 12,000 ft^3 @ SWMU 107, 80,000 ft^3 @ SWMU 119.1	3,407 yds	$ 3	$ 10,222
	Synthetic Membrane: 6000 ft^2 @ SWMU 107, 40,000 ft^2 @ SWMU 119.1	5,111 yds^2	$ 2	$ 10,222
	Drain Rock: 3,000 ft^3 @ SWMU 107, 20,000 ft^3 @ SWMU 119.1	851 yds	$ 12.50	$ 10,648
	Filter Fabric: 6,000 ft^2 @ SWMU 107, 40,000 ft^2 @ SWMU 119.1	5,111 yds^2	$ 2	$ 10,222
	Topsoil: 3,000 ft^3 @ SWMU 107, 20,000 ft^3 @ SWMU 119.1	850 yds	$ 7	$ 5,963
	Vegetate: 6,000 ft^2 @ SWMU 107, 40,000 ft^2 @ SWMU 119.1	1.06 ac	$ 1,110	$ 1,172
	Ditches: 320 ft. @ SWMU 107, 1,000 ft. @ SWMU 119.1	1,320 ft	$ 51	$ 6,600

TABLE 3-5
(CONTINUED)
ALTERNATIVE 5 (ENCAPSULATION)
ESTIMATED COSTS

	ITEM	UNIT(S)	UNIT COST	TOTAL
	Slurry Wall: 320 ft^2 @ SWMU 107 1000 ft^2 @ SWMU 119.1	13,200 ft^2	$ 6	$ 79,200
Sumps		2	$ 1,000	$ 2,000
Pump and Pipe		2	$ 1,000	$ 2,000
	TOTAL CAPITAL COSTS:			$143,249
OPERATING COSTS				
Maintenance				$ 10,000
Sumps			$10/month	$ 120
Environmental Monitoring:				
	GW Samples	15	$ 2,000	
	SW Samples	2	$ 1,500	
	Twice a year for 30 years			$ 66,000
	TOTAL ANNUAL OPERATING COSTS:			$ 76,120
PRESENT WORTH				$861,000

that are practical under the small soil depths in the area. Approximately 60 injection wells will be required to grout an area of about 6,000 square feet at SWMU 107.

However, immobilization using grout is expected to be effective in only a portion of the subsurface at SWMU 119.1 because of the stratified nature of the soils. It is anticipated that the gravel layers can be effectively sealed using grout, but that the clayey soils cannot. For costing purposes, it is assumed that injection holes on approximately 10 foot centers will be required. Approximately 400 injection wells will therefore be required to grout an area of 40,000 square feet at SWMU 119.1.

The performance of the system will be monitored by sampling wells and surface waters in the area. For conceptual design level costing purposes, it has been assumed that the monitoring program will be the same as described in the no-action alternative.

3.3.6.2 Effectiveness

It is expected that VOCs in the more permeable soils will be immobilized by the grout and thereby not be released to the ground water. Therefore, ground-water concentrations should decrease to levels that are lower than current levels, resulting in a reduction of risks to the public health and environment. However, because *in-situ* immobilization does not meet RCRA closure standards and is not expected to be completely effective, this alternative is considered one that does not meet ARARs but significantly reduces hazards to the public health and environment.

A small volume of existing contaminated ground water downgradient of the immobilization area at SWMU 119.1 will be allowed to flow toward the Valley Fill Alluvium. The compounds that enter the valley flow system are expected to be diluted and attenuated so that they are non-detectable at the property boundary (Indiana Street) and therefore do not pose a hazard to the public or the environment.

3.3.6.3 Acceptable Engineering Practice

The alternative uses standard technologies but they are not entirely appropriate for the conditions at the 881 Hillside. The creation of grouted hydraulic barriers is typically somewhat difficult, particularly in fine-grained materials. The task is even more difficult in stratified materials. Because of these difficulties, effective immobilization of the entire mass using grout is uncertain.

3.3.6.4 Cost Considerations

The capital cost of this alternative is approximately $1,829,000. The present worth, considering monitoring and operation and maintenance costs, is $2,451,000 using a 10% discount rate over thirty years. Costing information is presented in Table 3-6.

3.3.6.5 Conclusion

This alternative has not been retained for detailed evaluation because it offers less protection of public health and the environment at significantly greater cost when compared to other alternatives.

TABLE 3-6

ALTERNATIVE 6 (IMMOBILIZATION)
ESTIMATED COSTS

	ITEM	UNIT(S)	UNIT COST	TOTAL
CAPITAL COSTS				
Grouting:				
	Drilling (460 holes; 10 feet deep)	4,600 ft	$ 14.16	$ 65,136
	Grout Pipe	4,600 ft	$ 8.49	$ 39,054
	Grout (100 sq. ft./hole, 5' thick, porosity=.1)	172,027 gal.	$ 10	$1,720,269
	Placement of Grout (2 yds/hole)	920 yds	$ 5.66	$ 4,821
	TOTAL CAPITAL COSTS:			$1,829,281
OPERATING COSTS				
Environmental Monitoring:	GW Samples	15	$ 2,000	
	SW Samples	2	$ 1,500	
	Twice a year for 30 years			$ 66,000
	ANNUAL OPERATING COSTS:			$ 66,000
PRESENT WORTH				$2,451,000

3.3.7 Alternative 7: Treat Source Well & Footing Drain Flow

3.2.7.1 Description

This alternative involves pumping a source well (9-74) at SWMU 119.1 and collection of the footing drain discharge at SWMU 107 (Figure 3-10). The collected water will be treated in the new treatment plant and reinjection of treated water downgradient of the 881 Hillside Area in the Valley Fill Alluvium of the Woman Creek drainage. It is estimated that flow from a completely dewatered 9-74 will begin at about 1 gpm but rapidly fall to a steady flow of about 0.04 gpm. It is anticipated that the flow from the drain will vary between about one and five gpm although the flow may cease during periods of drought.

The performance of the system will be monitored by sampling wells and surface waters in the area. For conceptual design level costing purposes, it has been assumed that the monitoring program will be the same as described for Alternative 2.

3.3.7.2 Effects of the Alternative

Collection and treatment of the discharge from the footing drain will remove all of the VOCs currently being released to surface water. Pumping of well 9-74 will remove much of the highly contaminated ground water in the vicinity of SWMU 119.1. This alternative does not meet ARARs; however, it will significantly reduce contaminant migration and thus significantly minimize any threats to the public health.

3.3.7.3 Acceptable Engineering Practice

The alternative uses proven technologies.

3.3.7.4 Cost Considerations

The capital cost of this alternative is approximately $224,000. The present worth, considering monitoring and operation and maintenance costs, is $2,291,000 using a 10% discount rate over thirty years. Costing information is presented in Table 3-7.

3.3.7.5 Conclusion

This alternative has been retained because it prevents or minimizes future migration of hazardous substances and provides protection of the public health and environment, but does not meet ARARs.

3.3.8 <u>Alternative 8: French Drain with Soil Removal</u>

3.3.8.1 Description

This alternative involves excavation of contaminated soils from SWMU 119.1 and disposal at an off-site RCRA permitted disposal facility. Excavation and removal will be coupled with construction of a french drain (as in Alternative 3). Water collected from the drain plus a source well at SWMU 119.1 (well 9-74) and the Building 881 footing drain flow will be treated in a new treatment plant (see Section 4.2). Effluent from the treatment plant will be reinjection of treated water

TABLE 3-7

ALTERNATIVE 7 (SOURCE WELL & 107 SUMP) ESTIMATED COSTS

	ITEM	UNIT(S)	UNIT COST	TOTAL
CAPITAL COSTS				
Treatment Plant				$ 215,000
Source Well:				
	Pump and Piping	L.S.	$ 1,000	$ 1,000
	Sump at Footing Drain	L.S.	$ 8,000	$ 8,000
	TOTAL CAPITAL COSTS:			$ 224,000
OPERATING COSTS				
Treatment Plant O&M:				$ 81,000
	Source Well	12 mos	$10/month	$ 120
	103 Drain	12 mos	$10/month	$ 120
Environmental Monitoring:				
	GW Samples	15	$ 2,000	
	SW Samples	2	$ 1,500	
	Twice a year for 30 years			$ 66,000
Treatment System Monitoring:				
	4 Samples/ Month	48	$ 1,500	$ 72,000
	TOTAL OPERATING COSTS:			$219,240
PRESENT WORTH				$2,291,000

downgradient of the 881 Hillside Area in the Valley Fill Alluvium of the Woman Creek drainage.

It is estimated that approximately 3,000 cubic yards will be excavated from the area shown on Figure 3-11. The average excavation depth is estimated to be about 10 feet, with maximum cuts possibly as deep as 17 feet. Excavated material will be loaded directly into polyethylene lined haul trucks for transport to a RCRA permitted disposal facility. Inflow to the excavation will be removed by pumping, stored temporarily in an on-site tank, and then treated at the existing Rocky Flats Plant treatment facility.

The performance of the system will be monitored by sampling wells and surface waters in the area. For conceptual design level costing purposes, it has been assumed that the monitoring program will be the same as described for Alternative 2.

3.3.8.2 Effectiveness

Collection and treatment of the discharge from the french drain will remove all of the volatile organics in the ground water at the 881 Hillside. The drain will fully penetrate the soils and will provide a positive cutoff of water flowing toward it. Excavation of the source of contamination and collection of highly contaminated ground water near the source is expected to shorten the required treatment time. It is concluded that this alternative will meet or exceed ARARs.

There is some hazard to the public from the traffic generated by truck transport of the excavated soils. It is estimated that approximately 200 truck trips will be generated by this alternative.

3.3.8.3 Acceptable Engineering Practice

This alternative uses only proven technologies. It is expected to be highly effective in containing ground water. Partial excavation of the soils in the SWMU 119.1 area is expected to shorten the time that treatment is required.

3.3.8.4 Cost Considerations

The capital cost of this alternative is approximately $1,292,000. The present worth, considering monitoring and operation and maintenance costs, is $3,360,000 using a 10% discount rate over thirty years. Costing information is presented in Table 3-8.

3.3.8.5 Conclusion

This alternative has not been retained for detailed evaluation because the cost of this alternative is high relative to other alternatives that achieve the same level of environmental and public health protection.

3.4 SUMMARY OF SCREENING RESULTS

The above described remedial alternatives are presented and compared on Table 3-9. The table provides comparisons of environmental and public health benefits and order of magnitude cost estimates. On these bases, four of the alternatives are eliminated that do not provide adequate protection of public health, welfare, and the environment, or are much more costly without providing

TABLE 3-8

ALTERNATIVE 8 (DRAIN WITH PARTIAL SOIL REMOVAL) ESTIMATED COSTS

	ITEM	UNIT(S)	UNIT COST	TOTAL
CAPITAL COSTS				
Treatment Plant:				$215,000
French Drain:				$ 71,923
Soil Removal:				
	Excavation (100' x 10')	2,909 yds	$ 2.25	$ 6,545
	Transport	4,320 tons	$ 85	$367,174
	Disposal	4,320 tons	$ 140	$604,800
	Dewatering	10 days	$ 400	$ 4,000
	Backfill	2,909 yds	$ 4.75	$ 13,818
	Revegetate (100 ft dia)	0.18 ac	$1,100	$ 198
Source Well:				
	Pump and Piping	L.S.	$ 1,000	$ 1,000
	Sump at Footing Drain	L.S.	$ 1,000	$ 8,000
	TOTAL CAPITAL COSTS:			$1,292,414
OPERATING COSTS				
Treatment Plant O&M:				$ 81,000
	Drain System	12 mos	$10/month	$ 120
	Source Well	12 mos	$10/month	$ 120
	Footing Drain	12 mos	$10/month	$ 120

TABLE 3-8

ALTERNATIVE 8 (DRAIN WITH PARTIAL SOIL REMOVAL) ESTIMATED COSTS

	ITEM	UNIT(S)	UNIT COST	TOTAL
Environmental Monitoring:				
	GW Samples	15	$ 2,000	
	SW Samples	2	$ 1,500	
	Twice a year for 30 years			$ 66,000
Treatment System Monitoring:				
	4 Samples/ Month	48	$ 1,500	$ 72,000
	TOTAL ANNUAL OPERATING COSTS:			$219,360
PRESENT WORTH				$3,360,000

significantly greater protection. The following four alternatives are retained for detailed evaluation:

1. No action;

3. Collection of ground water using a french drain and a source well, collection of footing drain flow from SWMU 107, treatment of collected water in a new treatment plant and reinjection;

5. Total encapsulation of source areas using a multi-layer cap and slurry wall with control of gradients by pumping an internal sump (dewatering fluids to be treated at an existing treatment plant); and

7. Pump a source well at SWMU 119.1, collect footing drain flow from SWMU 107, treat collected water at a new treatment plant, and reinjection.

3.5 REFERENCES

Ellis, W.D., J.K. Payne, A.M. Tafuri, and F.J. Freestone, 1984, The Development of Chemical Countermeasures for Hazardous Waste Contaminated Soil, in 1984 Hazardous Material Spills Conference, Nashville, Tennessee.

EPA, 1984, Case Studies 1-23: Remedial Response at Hazardous Waste Sites, EPA-540/2 84-002b, U.S. Environmental Protection Agency, Cincinnati, Ohio.

EPA, 1985, Handbook, Remedial Action at Waste Disposal Sites (Revised), EPA/625/6-85/006, U.S. Environmental Protection Agency, Cincinnati, Ohio.

TABLE 3-9

SUMMARY OF INITIAL SCREENING OF ALTERNATIVES

	ACCEPTABLE ENGINEERING PRACTICES			EFFECTS OF ALTERNATIVE			
ALTERNATIVE	FEASIBILITY	TIME RE-QUIRED TO IMPLEMENT	RELIABLITY	ENVIRONMENTAL IMPACT	ABILITY TO PROTECT PUBLIC HEALTH AND ENVIRONMENT	RELATIVE COST	RESULT OF INITIAL SCREENING
1. No Action	N/A	0 months	-	Does not meet ARARS	Minimal Risk	Low	Consider further
2. Collection of GW with wells and source well; collection of footing drain flow from SWMU 107; treatment and reinjection	Fair	18-24 months	Fair	Meets ARARS Environmental Impacts temporary during construc-tion	Good	Moderate/High	Eliminated based on costs and reliability
3. Collection of GW with french drain and source well; collection of footing drain flow from SWMU 107; treatment and reinjection	Good	12-18 months	Good	Excavation of soil for french drains presents minimal exposure risk. Meets ARARS	Good	Moderate	Consider further based on feasibility and effectiveness
4. Collection of GW with french drain and source well: collection of footing drain flow from SWMU 107; treatment and split discharge between reinjection and soil flushing.	Good for collection and surface discharge; soil flushing unproven	12-18 months	Good for collection and surface discharge; soil flushing	Excavation of soil for french drains presents minimal exposure risk. Meets ARARS. No additional human health or envi-ronmental risks posed by soil flushing.	Good	Moderate	Eliminated based on unproven technology and consideration that the incremental benefit may not justify the increased costs.
5. Total Encapsulation with cap and slurry wall	Good	18-24 months	Good	Temporary and minor during construction. Does not meet ARARS initially	Minimal Risk	Low/Moderate	Consider further based on costs and reliability.

TABLE 3-9

SUMMARY OF INITIAL SCREENING OF ALTERNATIVES

	ACCEPTABLE ENGINEERING PRACTICES			EFFECTS OF ALTERNATIVE			
ALTERNATIVE	FEASIBILITY	TIME REQUIRED TO IMPLEMENT	RELIABLITY	ENVIRONMENTAL IMPACT	ABILITY TO PROTECT PUBLIC HEALTH AND ENVIRONMENT	RELATIVE COST	RESULT OF INITIAL SCREENING
6. Immobilization	Fair	12-18 months	Poor	Temporary and minor during construction; Does not meet ARARS	Minimal Risk	High	Eliminated based on costs and reliability
7. Collection of GW by one source well at SWMU 119.1 and collection of footing drain flow from SWMU 107; treatment and reinjection	Good	12-18 months	Fair	Alternative does not meet ARARS.	Acts to reduce continuing releases thereby minimizing human health and environmental risks	High	Retained because it provides significantly increased protection above that provided by "no action" alternative.
8. Collection of GW with french drain and source well at SWMU 119.1; collection of footing drain flow from SWMU 107; treatment and reinjection partial excavation of soils for off-site disposal	Good	18-24 months	Good	Meets ARARS	Good	High	Eliminated based on costs

SECTION 4

DETAILED EVALUATION OF REMEDIAL ALTERNATIVES

This phase of the feasibility study is the process of selecting the remedial action alternative that best satisfies the site objectives, and involves a detailed analysis of screened developed alternatives. These alternatives are:

1) No action;

2) Collection of ground water using a french drain and a source well, collection of footing drain flow from SWMU 107, treatment of collected water in a new treatment plant and reinjection;

3) Total encapsulation of source areas using a multi-layer cap and slurry wall with control of gradients by pumping an internal sump (dewatering fluids to be treated at an existing treatment plant); and

4) Pump a source well at SWMU 119.1, collect footing drain flow from SWMU 107, treat collected water at a new treatment plant, and reinjection.

In addition, the screened ground-water treatment technologies are subjected to a detailed evaluation to determine the preferred process for water treatment.

The section begins with a description of the detailed evaluation process. The alternatives are then evaluated on the basis of cost and non-cost criteria.

4.1 INTRODUCTION

This section presents detailed evaluations of the retained alternatives using objectives and criteria defined in both the Remedial Action Phase VI (Section 300.68) of the National Oil and Hazardous Substances Contingency Plan (NCP) as amended on

November 20, 1985, and the National Environmental Policy Act (NEPA). The evaluation criteria are:

1) Non-cost Analysis

   - Technical Evaluation
   - Institutional Requirements
   - Public Health Issues
   - Environmental Issues

2) Cost Analysis

These criteria are discussed in the subsections that follow.

4.1.1 Non-Cost Analysis

4.1.1.1 Technical Evaluation

Each remedial alternative is evaluated on the basis of the following criteria.

- Performance - Two aspects of remedial actions determine their desirability on the basis of performance: effectiveness and useful life. Effectiveness refers to the degree to which an action will prevent or minimize substantial danger to public health, welfare, or the environment. The useful life is the length of time this level of effectiveness can be maintained.

- Reliability - To be reliable, a potential remedial action alternative should incorporate proven technologies that have a demonstrated and dependable record of use, and should be capable of accomplishing the desired corrective results over the planned life of the remedial action. Also, the frequency and complexity of necessary operation and maintenance should be considered in evaluating the reliability of alternatives.

- Implementability - Another important aspect of remedial alternatives is their implementability - the relative ease of installation and the time required to achieve a given level of response. The time requirements can be generally classified as the time required to implement a technology and the time required before results are actually realized.

- Safety - Each remedial alternative can be evaluated with regard to safety. This evaluation can include short-term threats to the safety of nearby communities, the environment, and workers during implementation.

The 881 Hillside feasibility study considers a variety of options, including the technologies outlined in the NCP that have proven track records of meeting the above described technical objectives at other sites. All technologies incorporated in the remedial alternatives for the 881 Hillside are technically feasible, although their success in meeting the technical objectives is variable.

4.1.1.2 Environmental and Public Health Issues

The remedial action selected must adequately protect public health, welfare, and the environment. Documentation that the action adequately controls the long-term effects of any residual contamination, and protects the public health both during and after the action is required. Applicable health and environmental health standards are used to evaluate each alternative.

The overall goal of the selected remedial action program is to mitigate the existing environmental threats without creating additional adverse effects. The environmental effectiveness evaluation criterion focuses on the key environmental contaminants. The environmental effectiveness of each potential remedial action alternative is evaluated according to the requirements outlined in the NCP. The factors to be incorporated into the environmental effectiveness evaluations include the following:

- o The likelihood of on-site source control or off-site remedial actions being effective to mitigate and/or minimize the threat to public health and welfare.
- o The prevention of additional environmental (soil, surface water, and ground water) contamination.

- The potential for adverse environmental effects (resulting from the alternative or its implementation).

In considering the environmental effectiveness of remedial alternatives for the 881 Hillside, the following more specific goals have been identified:

- Protect local residents from ingesting contaminated water.
- Protect the residents from contacting waste material or contaminated water.
- Control the long-term leaching of identified substances.
- Minimize or prevent continued ground-water contamination.
- Control run-off or surface water impacts from on-site remedial actions.
- Properly dispose of any contaminated materials that must be excavated and/or removed from the site.

During the evaluation of on-site source control remedial actions, worker health and safety must be considered. Any measures that have the potential for worker contact or release of hazardous substances must conform to Occupational Safety and Health Act (OSHA) requirements.

4.1.1.3 Institutional Requirements

Political and regulatory factors can be critical to the overall implementability and selection of an effective remedial action. The institutional evaluation is largely one of assessing the extent each alternative attains action, location, and chemical specific ARARs.

4.1.2 Cost Analysis

4.1.2.1 Introduction

Cost analyses are required to compare alternatives of similar effectiveness and feasibility during remedy selection. These analyses include:

- o Capital Cost Estimates for Each Alternative;
- o Operation and Maintenance Cost Estimates for Each Alternative;
- o Present Worth Analysis for Life Cycle Costs; and,
- o Sensitivity Analysis of the Cost Estimates.

In accordance with the provisions of the National Contingency Plan (NCP), cost estimates have been prepared for the screened remedial alternatives. The NCP requires that cost estimates be prepared within an accuracy range of -30% to +50% of the actual implementation cost of each alternative. Because of Rocky Flats Plant budgetary requirements, the accuracy of the cost estimates are more realistic than typically required by the NCP.

A discussion of costs for each alternative is presented in Section 4.4.

4.2 GROUND-WATER TREATMENT

The ground-water treatment technologies selected for detailed evaluation in the screening of alternatives section of this document (Section 2) are carbon adsorption, UV/peroxide, and air stripping. The merits of each system are explained in Sections 4.2.1, 4.2.2, and 4.2.3. Section 4.2.4 identifies the preferred treatment system and the reasons for the selection. References to specific products or companies is not intended as an endorsement or commitment by Rockwell International to that product or company. The systems listed are provided as examples of units that should provide the level of treatment needed to meet chemical specific ARARs for the organic contaminants. It is recognized that many companies provide similar treatment systems, however, the system ultimately selected for installation will be required to provide the same level of efficiency.

4.2.1 Activated Carbon Adsorption

Granular activated carbon is a proven technology for removing volatile organic compounds from water. The process has been shown to decrease VOC concentrations to levels that comply with regulatory requirements.

4.2.1.1 Performance

Based on the results of the Accelerated Column Test, contaminant breakthrough for the lead vessel is estimated to occur every 45 days (based on an assumed combined flow rate of 10 gpm) if methylene chloride is present, and every 125 days for 1,1,1-trichloroethane. A polish vessel will ensure removal of the contaminants before discharge of the treated effluent.

The carbon adsorption system is expected to be continuously operated, with no loss of efficiency, until the quality of the ground water improves to the level that further treatment is deemed unnecessary. The only factor that will affect the efficiency of the treatment is the quality of the carbon in the vessels. As long as the carbon is changed whenever breakthrough occurs, the carbon system should remove ground-water contamination to regulatory limits for as long as is needed.

4.2.1.2 Reliability

The carbon adsorption system will require minimal operational and maintenance support. The system will have a warning system to alert operators if problems develop. Contaminated water will be collected in two surge tanks (15,000 gallons per tank) to contain daily flows, expected to average less than 10 gpm (14,400 gallons/day). At a flow rate of 30 gpm through the treatment unit, the tanks will drain in approximately 8 hours; therefore, the system will be operated during normal working hours. It is estimated that approximately 2 man-hours of operator time will be needed daily, primarily to start up, shut down, and monitor the system. Carbon changeout time is averaged into the two man-hours per day.

One vessel of carbon is estimated to last 45 days before the carbon must be replaced. Change-out of the carbon will require attaching an eductor assembly to the vessels for removing the spent carbon and adding new carbon. In addition, normal maintenance of pumps, etc. is required. Overall maintenance requirements are estimated to be 16 hours per month.

EPA (Federal Register, Vol. 52, No. 130, page 25698) has designated carbon adsorption a "Best Available Technology" for the removal of seven specific volatile organic compounds (including TCE, 1,2-DCA, and 1,1,1-TCA) from drinking water.

4.2.1.3 Implementability

Treatment of the 881 Hillside ground water will not require a complex carbon adsorption system; therefore, based on the ACT test and low projected flows through the system, a standard carbon adsorption unit (Model 3 Dual Module Adsorber from

Calgon Carbon Corporation) was chosen to represent the type of system that will be of sufficient capacity. This standard unit can be shipped and readily installed in the treatment building. After performing adjustments, the system should be ready to operate at full capacity.

The Model 3 unit is a fixed-bed, dual-vessel, system that would be used in series. Water will be pumped to the top of the lead (first) treatment vessel, exit the bottom, and then enter the top of the polish (second) vessel. The two vessels are approximately 10 feet tall (excluding piping) and four feet in diameter (surface area 12.6 square feet), contain 2,000 pounds of carbon each, and have a series flow capacity of 65 gpm. During treatment, water will flow through these vessels at approximately 30 gpm in a batch operation. This will provide a hydraulic loading of approximately 2 gpm/ft^2 of surface area. Contact time will be approximately 30 minutes (total for both vessels). The pressure in the vessels will be a maximum of 75 psi.

There are currently some questions regarding radionuclide loading on the carbon. Experimental analyses will be performed to evaluate if this will be a problem. If the carbon has radioactive activity sufficiently high to be considered radioactive by the regeneration facilities, then the facilities may not accept the spent carbon. The spent carbon will have to be packaged and then shipped to the Nevada Test Site as a mixed waste for disposal. Disposal costs will add to the cost of the operation.

4.2.1.4 Safety

All appropriate safety measures required when moving and installing large equipment will be complied with during installation. The operation of the system and handling of the spent carbon will be by personnel that are properly supervised and trained in the handling of hazardous and radioactive wastes. Because carbon will remove oxygen from the air, any time personnel are working in confined areas (i.e., tanks) where oxygen may be limited, special care must be taken to ensure that an adequate air supply is available.

Nearby communities and the environment should realize no safety concerns as this treatment process will effectively remove organic contaminants from the ground water. Treated water will be monitored to ensure contaminants are within regulatory guidelines before being released to the environment. No short-term safety concerns for nearby communities and the environment are anticipated during implementation of the process.

4.2.1.5 Estimated Costs

Results of the Accelerated Column Test indicate the carbon usage rate will be 3.1 pounds per 1,000 gallons of ground water, based on breakthrough of methylene chloride. At a cost of approximately $0.90 per pound for regenerated carbon, the annual costs are estimated to be $15,000 for carbon (this is based on an assumed combined average flow rate from the different water sources of 10 gpm). The cost of shipping contaminated carbon (as a manifested waste) for regeneration or disposal is estimated to be $2,500 (the costs could vary substantially) and $500 for receiving fresh carbon, for a total of $3,000 per 2,000 pound load. Labor needed to operate the system is expected to average two man-hours per day at a burdened labor rate of approximately $61 per hour. Maintenance requirements are estimated to average 16 hours per month at a burdened labor rate of $50 per hour.

Using the preceding information, the estimated costs for installing a carbon adsorption facility are shown in Table 4-1.

4.2.2 Ultraviolet (UV)/Peroxide Oxidation

4.2.2.1 Performance

Technology screening of the UV/peroxide technology indicated that this technology has potential application at the 881 Hillside. Bench-scale studies, using 881 Hillside Area water, were then conducted by Peroxidations Systems, Inc. The bench-scale testing provided for a dynamic flow simulation of actual operating conditions of a full-scale UV/peroxide ground-water treatment system. Parameters investigated during the testing included hydrogen peroxide (H_2O_2) dosage and power requirements, retention time, system pH, and influent/effluent conditions. Contaminant concentrations were reduced to non-detectable levels for initial ground-water influent total VOC concentrations of 1 ppm. These results indicate that the UV/peroxide ground-water treatment process is capable of adequately treating the contaminated 881 Hillside Area water, and thus, will effectively minimize any substantial danger to public health, welfare, or the environment.

Operating conditions were projected for a full-scale UV/peroxide treatment unit using the bench-scale results provided by Peroxidation Systems, Inc. The recommended UV/peroxide treatment unit consists of an 80-gallon stainless steel

TABLE 4-1

ESTIMATED COSTS FOR CARBON ADSORPTION SYSTEM

Item	Capital Cost (Dollars)	Annual Cost (Dollars)
Building improvements, utilities	150,000 ****	
Carbon Treatment System	50,000	
Carbon Bulk Bin	No Cost	
Eductor Assembly	7,000	
Annual Costs		
Carbon Purchases (~8 loads/yr)		15,000
Shipping (~7 loads/yr)*		24,000
Preparation (7 hr/mon) & Disposal (~!8 loads/yr)**		9,000
Operator Costs (2 hr/day, 365 days/yr)		45,000
Maintenance Costs (8 hr/month)		5,000
TOTAL	207,000	89,000 *** 98,000

* May vary substantially

** This is needed if the carbon is sent to the Nevada Test Site for disposal.

*** Includes preparation and disposal costs.

**** Does not include the cost of shipping and setup.

oxidation chamber, which provides for a maximum ground-water retention time of 2.66 minutes at a constant system flowrate of 30 gpm. The oxidation chamber contains 4 medium pressure UV lamps, which are mounted horizontally in quartz sheaths. A hydrogen peroxide feed system is used to inject approximately 50 mg/l (per ppm of contaminants) of a 50 percent H_2O_2 solution into the ground-water feed line. The ground-water/peroxide mixture then passes through an in-line static mixer before entering the bottom of the oxidation chamber. The ground water than flows through the reaction chamber, passing the UV lamps, before it exits the top of the oxidation chamber. Flow through the oxidation chamber will be turbulent in nature to provide for the optimum degree of contaminant oxidation. As the ground water passes the UV lamps, the contaminants will be effectively destroyed to non-detectable levels.

It is expected that this treatment process, with proper maintenance, will provide the desired level of contaminant destruction until complete remediation of the 881 Hillside has been achieved.

4.2.2.2 Reliability

UV/peroxide oxidation is an innovative technology currently being developed for the complete destruction and detoxification of hazardous organic compounds in aqueous solutions. Although the technology is relatively new and has had limited application in the field, SARA requires EPA to prefer remedial actions that significantly and permanently reduce the toxicity, mobility, or volume of hazardous wastes by employing innovative technologies that result in the destruction or detoxification of the wastes.

Demonstrated performance of the UV/peroxide ground-water treatment system has been somewhat limited due to the relatively new development of the process. However, Peroxidation Systems, Inc. has 6 UV/peroxide units currently operational or on-line and ready for operation. One of these units is located at Rocketdyne's Santa Susana facility in California. Pilot scale operations were performed by Peroxidation Systems, Inc., on ground water containing VOC's (TCA, TCE, etc.) at system flow rates of approximately 20-40 gpm. Results from the pilot scale testing were favorable, and a UV/peroxide ground-water treatment unit has been purchased, set-up, and site tested. Another UV/peroxide ground-water treatment system, located locally, was visited and appeared to be a low maintenance, highly effective ground-water treatment unit. This system was treating ground water with TCA concentrations significantly lower than those found at the 881 Hillside (approximately 7 ppb). However, the treatment process had initially treated ground water with much higher concentrations. Based upon actual bench scale results using 881 Hillside ground water and information received regarding currently functioning treatment systems, the innovative UV/peroxide ground-water treatment system appears to be a reliable treatment technology.

Operating and maintenance requirements for the UV/peroxide treatment system are relatively minor. The system will require approximately 20 kW of power and 2,100 pounds/year of 50 percent H_2O_2 solution for normal operation. Routine maintenance of the equipment is required and the UV lamps will require replacement approximately every 3-6 months. Routine system maintenance is estimated to be approximately 16 hours/month. All four system UV lamps can be exchanged in about an hour. An advantage of this system is that the contaminants are destroyed in the ground water, thus, eliminating the need for off-site disposal of any waste generated during treatment, e.g., carbon. The system requires only occasional observation to ensure the system is operating properly, although system alarms will notify operators if a problem does occur. It is estimated that a maximum of 2 man-hours/day will be devoted to the operation of the system and the process equipment in the area.

4.2.2.3 Implementability

The commercially available UV/peroxide ground-water treatment system would be installed upon completion of the treatment plant building. The UV/peroxide system could be fully operational within a month after delivery.

4.2.2.4 Safety

During implementation and operation of the UV/peroxide ground-water treatment unit, workers need to be aware of two potential hazards. The treatment unit uses 50 percent hydrogen peroxide solution and ultraviolet lamps to achieve contaminant destruction. Use of hydrogen peroxide, a strong oxidizer, will require that operators are aware of this potential hazard. The H_2O_2 feed tank will be properly vented to assure no pressure buildup. Existing Rockwell Health, Safety and Environment guidelines at Rocky Flats regarding operator safety while working with strong oxidizers will be followed. The system is locked during operation and has UV filters on view ports to prevent worker exposure to UV light. UV lamps operate utilizing high voltage, and thus, caution must be used when working with the system and during the periodic replacement of the UV lamps. In event of a system failure, no safety hazards are anticipated. The treatment unit and the H_2O_2 feed pump will be shutdown and ground water will be collected in the surge tanks until the system is operational again.

Nearby communities and the environment should realize no safety concerns as this treatment process will effectively destroy ground-water contaminants. No off-site transportation and disposal of waste is required because the contaminants are destroyed during the treatment process. Treated water will be monitored to ensure contaminants are within regulatory guidelines before being released to the environment. No short-term safety concerns for nearby communities and the environment are anticipated during implementation of the process.

4.2.2.5 Estimated Costs

Estimated costs for the UV/peroxide ground-water treatment unit are shown in Table 4-2. Capital cost for the UV/peroxide ground-water treatment system is approximately $53,000. Operational costs include procurement of hydrogen peroxide (2,100 pounds/year), power utilization (20 kW), replacement parts (5% of capital), lamp replacement (every 3-6 months at a cost of $300/lamp), and routine daily operation (2 hours/day maximum) and maintenance (16 hours/month). Operational costs are based on a continuous system flow rate of 10 gpm. Daily operational and maintenance costs are derived from labor rates of $61/hour and $50/hour, respectively.

4.2.3 Air Stripping with Off-Gas Treatment

4.2.3.1 Performance

Technology screening of the air stripping system (packed tower aeration) indicated that this technology has potential application at the 881 Hillside.

TABLE 4-2

OVERALL COSTS FOR THE UV/PEROXIDE GROUND-WATER TREATMENT UNIT

ITEM	CAPITAL COST (Dollars)	ANNUAL COST (Dollars)
Building improvements, utilities	150,000	
Treatment Unit & Equipment		
- UV/Peroxide Unit	$60,000	
- H_2O_2 tank and pump	5,000	
Operating Costs		
- Hydrogen Peroxide ($0.52/lb.*)		$14,000
- Power ($0.07/kwh)		12,000
- Lamp Replacement (every 3 months)		5,000
- Operations ($61/man-hour)		45,000
- Maintenance ($50/man-hour)		5,000
TOTAL:		
- UV/Peroxide	$215,000	$81,000

* Hydrogen peroxide costs are based on the purchase of five 500-pound drums of 50% solution.

The air stripper will be used in conjunction with both a liquid and a vapor phase activated carbon adsorption system to treat contaminated ground water from the 881 Hillside Area. The air stripper alone will remove greater than 99% of the contaminants in the ground water. However, the air stripper is sensitive to fluctuations in ground-water flow rates and contaminant concentrations. Therefore, a liquid phase carbon adsorption unit will be placed in series with the air stripper to enhance system performance and to ensure that the treated effluent meets regulatory standards regarding contaminant concentrations.

During the air stripping process, VOCs are transferred from the ground water to the vapor phase. The vapor phase may require treatment to meet Colorado Department of Health air quality standards. Therefore, a vapor phase carbon adsorption system has been included as a conservative cost estimating measure.

An air stripper system coupled with liquid and vapor phase carbon adsorption is a proven technology that has a dependable record of use. It is expected that this treatment process, with proper maintenance, will provide the desired level of contaminant destruction until complete remediation of the 881 Hillside has been achieved.

4.2.3.2 Reliability

The use of an air stripper is a highly effective method of removing hazardous volatile organic compounds (VOCs) from ground water. The efficiency of the process is well documented. The Environmental Protection Agency (Federal Register, Vol. 52, No. 130, page 25698) has designated packed tower aeration along with granular activated carbon, as a Best Available Technology (BAT) for the removal of VOCs from drinking water.

Influent contaminated ground water will enter the top of the 22-inch diameter, 34-foot air stripping column and subsequently contact clean air supplied through the bottom of the column (column sizes are approximate). Appropriate air to water flow rates will be utilized to provide for the optimum (99+%) mass transfer of the contaminants from the ground water to the air stream. The treated ground water will then pass through a 1,000 pound disposable liquid phase carbon treatment unit. Based on a constant yearly flow rate of 10 gpm, carbon usage will be approximately 8 pounds/day and each 1,000 pound carbon unit will require replacement approximately every four months. Transport and disposal of the spent carbon unit will be required. Treated ground water exiting the carbon unit will contain less than 1 ppb of the volatiles identified in the ground water at the 881 Hillside. If required, air exiting the air stripper, will pass through a unit containing 1,500 pounds of vapor phase activated carbon. Based on an average flow rate of 10 gpm, carbon usage will be approximately 7 pounds/day and each 1,500 pound carbon unit will require replacement approximately every seven months. A heater may be utilized to obtain a lower relative humidity to maximum removal efficiencies. Return of the now hazardous carbon for regeneration will be required. All carbon usage rates are approximate, as no bench scale testing has been done.

Operation of the treatment process is relatively simple, requiring occasional cleaning of the air stripping column and replacement of carbon. The air stripper will require cleaning to remove scale buildup on the packing material in order to maintain optimum removal efficiency. It is anticipated that the liquid phase carbon will require replacement approximately every four months (based upon a constant yearly flow rate of 10 gpm). Vapor phase carbon is expected to last approximately seven months. Transportation and disposal of the liquid phase carbon at either a hazardous waste facility or at the Nevada Test Site is a concern that has been previously discussed.

Routine maintenance of the equipment, including carbon replacement and packing material cleaning and replacement, is estimated to require approximately eight hours/month. The system requires only occasional observation to ensure the air stripper is operating properly; however, system alarms will notify operators if a problem does occur. It is estimated that a maximum of two man-hours/day will be devoted to the operation of the system.

4.2.3.3 Implementability

The air stripping ground-water treatment system is available commercially and could be implemented upon completion of the treatment plant building. Possible delays in implementation could result from the securing and insulating of the exposed portion (approximately 20 feet) of the air stripping column.

4.2.3.4 Safety

During implementation and operation of the air stripping ground-water treatment unit, workers need to be aware of potential hazards involving the handling of spent hazardous carbon (see Section 4.2.1.4). However, the liquid phase carbon will not require the same amount of handling as with the stand-alone carbon treatment system, since the carbon is contained in a disposable container, which is appropriate for transportation to a hazardous waste disposal facility. In the remote possibility that the liquid phase carbon becomes a mixed hazardous waste, the carbon and disposable container will be disposed of as described in Section 4.2.1.3.

Nearby communities and the environment should realize no safety concerns as this treatment process will effectively remove ground-water organic contaminants. Treated water and air will be monitored to ensure contaminants are within regulatory guidelines before being released to the environment. No short-term safety concerns for nearby communities and the environment are anticipated during implementation of the process.

4.2.3.5 Estimated Costs

Estimated costs for the air stripping ground-water treatment unit are shown in Table 4-3. Capital cost for the air stripper system is approximately $17,000. Replacement costs for the carbon are estimated to be $11,000 for the liquid phase carbon (based on three replacement units/year and $3,500/replacement unit) and $13,000 for the vapor phase carbon (based on 1.6 replacement units/year and $8,000/replacement unit). Operational costs are based on a continuous yearly operation at a system flow rate of 10 gpm. Operational costs must also include transport and off-site disposal of spent liquid phase carbon. Transportation of the vapor phase carbon is included in the previous cost estimate. It is estimated that the cost of preparing, shipping, and disposing of contaminated carbon as a manifested waste is $2,500 and the cost of receiving a fresh carbon unit is $500, for a total of approximately $3,000/2,000 lb load. These costs may vary substantially. Replacement of the spent carbon and other routine system maintenance is estimated to require 16 man-hours/month. Daily operation, which includes an occasional observation of the system to ensure proper operation, is estimated at a maximum of two man-hours/day.

TABLE 4-3

OVERALL COSTS FOR THE AIR STRIPPER GROUND-WATER TREATMENT UNIT

ITEM	CAPITAL COST (Dollars)	ANNUAL COST (Dollars)
Building improvements, utilities	150,000	
Treatment Unit & Equipment		
- Air Stripper Column	$12,500	
- Possible ancillary equipment (heater, extra blower)	2,000	
- Liquid Phase Carbon System	3,500	
Operating Costs		
- Liquid carbon phase replacement (3 units/year)		$11,000
- Vapor Phase Carbon Replacement (1.6/year)		13,000
- Transportation and Disposal of Spent Liquid Phase Carbon		9,000
- Operations ($61/man-hour)		45,000
- Maintenance ($50/man-hour)		5,000
TOTAL:		
- Air Stripper System	$167,000	$83,000

* Operating costs are based upon continuous yearly flowrate of 10 gpm.

Daily operational and maintenance costs are derived from labor rates of $61/hour and $50/hour, respectively.

4.2.4 Conclusion

The three proposed processes for treating ground water at the 881 Hillside compare favorably on the basis of cost. Tables 4-4 and 4-5 show the estimated capital costs, operating costs, and present worth for each treatment alternative. The 30-year present values of the air stripping and UV/peroxide systems are approximately $1,050,000, while the carbon adsorption system is $1,135,000.

Based on performance, reliability, implementability, safety, and environmental and institutional impacts, there is not a substantial difference between the three processes. Since all three processes will effectively decontaminate the ground water, the choice of treatment is based on expediency in destroying the ground-water contaminants. SARA favors innovative treatment technologies that destroy contaminants, and UV/peroxide meets this objective. Air stripping and carbon adsorption use activated carbon, and with regeneration, the contaminants that have adsorbed onto the carbon would eventually be destroyed. However, this assumes that the carbon is not radioactively contaminated, thereby requiring shipment to the Nevada Test Site for disposal. Therefore, the advantage provided by a UV/peroxide system of directly destroying the ground-water contaminants is the deciding factor in selecting UV/peroxide as the preferred process for ground-water decontamination.

TABLE 4-4

COST COMPARISONS FOR TREATMENT ALTERNATIVES

	Carbon Adsorption		UV/Peroxide		Air Stripping	
	Capital	Operating	Capital	Operating	Capital	Operating
Treatment System	207,000		215,000		167,000	
Hydrogen Peroxide				14,000		
Power				12,000		
UV Lamps				5,000		
Liquid Phase Carbon Replacement		15,000				11,000
Transportation		24,000				9,000
Vapor Phase Carbon Replacement						13,000
Maintenance		5,000		5,000		5,000
Operations		45,000		45,000		45,000
TOTALS:						
Capital	207,000		215,000		167,000	
Operating		89,000		81,000		83,000

TABLE 4-5

PRESENT WORTH ANALYSIS FOR THE TREATMENT ALTERNATIVES (10% DISCOUNT RATE)

Treatment	10 Year	20 Year	30 Year
Carbon Adsorption	843,000	1,054,000	1,135,000
UV/Peroxide	794,000	986,000	1,060,000
Air Stripping	760,000	957,000	1,032,000

4.3 DETAILED EVALUATION OF REMEDIAL ACTION ALTERNATIVES

4.3.1 No Action

4.3.1.1 Technical Evaluation

The No Action Alternative is presented as a basis for analysis of the potential environmental and public health impacts posed by the 881 Hillside Area with no remedial controls except monitoring and for comparison with the other remedial action alternatives. Under the No Action Alternative, no remedial activities will be taken at the site.

This alternative includes a long-term monitoring program to provide information concerning the contaminated ground-water plume location and concentrations. Regular long-term monitoring is required under this alternative due to the unknowns involving attenuation and migration of the leachate plume.

Since no remedial actions are taken under this alternative, a technical evaluation is not applicable under this alternative. Existing monitoring wells will be used for the long-term ground water monitoring program.

4.3.1.2 Environmental and Public Health Evaluation

At present conditions, the major environmental impact of the 881 Hillside Area is the local contamination of ground water. The No Action Alternative does not provide for effective environmental management nor control of the contaminated ground water. Environmental management would include management of the pathways in which contaminated ground water leaves the site. The No Action Alternative does not meet the remedial action objectives.

The primary public health concern of the No Action Alternative is the possible health risk resulting from the potential contamination of off-site ground water (and surface water through interconnection) that is used as a drinking water supply.

Some attenuation of organics by soils, as well as some dilution by the ground water flow is expected. It is not known, however, to what levels all the concentrations will be reduced or the time it will take to reduce concentrations to acceptable standards. Therefore, a potential for human exposure by ingestion of organic compounds in concentrations above the drinking water criteria is associated with this alternative. The reader is referred to Appendix 1, the Risk Assessment, for a quantitative assessment of health risks due to exposure to contaminants at the 881 Hillside Area and off-site at the property boundary for the no action alternative. It is concluded this alternative does not meet the remedial action objective of reducing or eliminating exposure to site contaminants by potential receptors by controlling containment pathways.

4.3.1.3 Institutional Evaluation

This alternative is considered not acceptable due to the potential for non-compliance with RCRA Subpart F ground-water protection requirements, and thus the potential for eventual off-site ground-water contamination. Other institutional requirements included in this alternative would be a provision for long-term, regularly scheduled site inspections and monitoring of the contaminated ground water concentrations and water table levels.

4.3.2 French Drain with Ground-Water Treatment

4.3.2.1 Technical Evaluation

Performance

A french drain is expected to be highly effective in containing and collecting ground water at the 881 Hillside. Drains for containment and collection of contaminated ground water have been successfully used for many years. When the drain can be keyed into a low permeability base and backed up with a downstream, low permeability wall, a french drain is the most positive method of ground-water control available. As such, the drain proposed in this alternative is expected to effectively contain all ground-water flow from the area. If all ground-water flow from the area is contained, there will be no releases of dissolved volatile organics to the environment.

The useful life of the french drain system is expected to be at least thirty years. The drain design provides for clean-outs at regular distances along its length which can be used for both mechanical and chemical cleaning, should this be required. Replacement of the pumps in the central sump should be expected as part of routine operation.

Reliability

French drains have been used successfully for many years for control of ground water. French drains are almost always effective, except when ground water can flow over, under or around the drain, or when the drain becomes clogged. The drain proposed for the 881 Hillside will fully penetrate the colluvium and be keyed into claystone bedrock, precluding the possibility of flow under or over the drain. It extends uphill on the west side to an elevation equal to that of SWMU 107 and is keyed into a dry ridge on the east end. This should preclude flow around the drain. Clogging is not expected to be a problem because the footing drain at Building 881 has been in service since the early 1950's without clogging.

Operation and maintenance requirements are small for a french drain. Flow to the sump is by gravity. Liquid level controllers switch on a submersible pump in the central sump whenever there is sufficient water present. Pumping records should be reviewed regularly to be sure that the system is operating. If long periods of non-pumpage are observed, water levels in the drain should be investigated to determine if the pumps have failed or if clean-out is required. In addition, ground-water and surface water conditions will be monitored. Thus, routine operational requirements are minimal.

Implementability

Implementation of this alternative involves only routine construction procedures. Construction of the drain can be completed in a period of approximately two months. Ground water will be effectively contained at the beginning of construction when the excavation is dewatered. The system will be operational immediately upon completion.

Safety

Worker safety precaution will be required during construction of this alternative because of the potential for encountering contaminated water in the excavation. However, at the location of the drain it is expected that contaminant levels in both soil and water will be low.

4.3.2.2 Environmental and Public Health Evaluation

This alternative prevents ground-water contamination from moving beyond the 881 Hillside Area which in turn will eliminate any future public exposure to ground-water contaminants off-site. Alluvial ground water flowing through the site will continue to move contaminants away from the site and into the french drain for subsequent removal by the treatment system. There are no adverse environmental effects that would result from implementation of this alternative.

4.3.2.3 Institutional Evaluation

Action specific ARARs relating to soil excavation which are pertinent to this alternative include the requirements under RCRA that address the storage of RCRA wastes in waste piles, and restrictions on the land disposal of solvent containing wastes that exceed treatment based standards for those constituents. Although the majority of the soil excavated during the installation of french drains will not be moved to another location (i.e. it will be used as backfill for the trenches from which it was excavated) thereby not triggering the land disposal restrictions, the temporary storage of the potentially contaminated soil in accordance with RCRA storage in

4.3.3 Total Encapsulation

4.3.3.1 Technical Evaluation

Performance

The total encapsulation system involves a three layer RCRA style cap, a soil-bentonite slurry wall keyed into claystone bedrock and an internal sump to maintain inward gradients. Infiltration and ground-water flow through the SWMUs is expected to be practically eliminated by the total encapsulation system. As a consequence, the release of volatiles from the SWMUs is also expected to be eliminated. It must be noted that the system will not be as effective if the SWMU areas are not underlain by continuous claystone.

The useful life of the total encapsulation system is expected to exceed thirty years. The containment features involving geologic materials (slurry wall and compacted soil cover) should function indefinitely, particularly given that flow through them will be from the non-contaminated to the contaminated side. The synthetic membrane can be expected to function adequately for at least twenty years, and it is backed-up by the compacted soil layer. The vegetated cover and peripheral ditches will require regular maintenance, and the internal sump will require regular operation.

Reliability

The technologies proposed in this alternative are all proven technologies. The multi-layer cap system has been used for nearly ten years with good success at many sites. Soil-bentonite slurry walls have also been used for many years to effectively control ground-water flow. The gradient control provided by the sump is a modification of the standard encapsulation system and should provide an extra level of protection.

Operation and maintenance requirements are very small for the total encapsulation alternative. There are essentially no operational requirements, with the exception of routine pumpage of the sump. This is expected to be required no more frequently than annually after the initial dewatering. Maintenance will involve inspection and cleaning of peripheral ditches, inspection and repair of the vegetated cover, and inspection and replacement of the sump pump. In addition, ground-water and surface water conditions in the vicinity of the Hillside will be monitored.

Implementability

This alternative can be implemented using standard construction practices. Seaming of synthetic membranes has become common enough that a qualified local contractor can probably be found. Construction of the encapsulation systems will probably require about three months.

Construction of a slurry wall at SWMU 119.1 may prove impractical where the wall runs parallel to the grade (slope may be too steep). For the two legs of the wall running up the hill, it is recommended that a compacted soil cutoff wall be constructed in an excavated trench. The trench will probably vary from about 15 feet deep at the downhill end to about 2 feet deep at the uphill end. The trench can be excavated with standard earth-moving equipment (e.g., scrapers). Some of the excavated material may be suitable for use in constructing the wall. The length of compacted wall is estimated to be 600 feet, while the remaining slurry portion is about 400 feet long. A compacted soil wall is expected to provide equal performance characteristics as a slurry wall.

Material for construction of the compacted soil cover and wall can be obtained from the Arapahoe Formation. The Arapahoe is covered by a thin veneer of colluvium along Woman Creek and could be excavated from a number of nearby areas; however, in order to avoid oversteepening the slopes, the borrow area should probably be established on the south side of Woman Creek.

Partial control of the SWMUs will be achieved as soon as the peripheral containment structures are constructed. Full control will not be achieved until the entire system is complete and pumping of the sumps begins.

Safety

Worker safety precaution will be required during construction of this alternative and during monitoring and dewatering operations. In addition, safety precautions will be required during excavation for and construction of the compacted soil barrier walls.

4.3.3.2 Environmental and Public Health Evaluation

This alternative will adequately contain and immobilize the sources of contamination. As discussed in Section 3, a small quantity of contaminated ground water is known to exist downgradient of SWMU 119.1 and may exist downgradient of SWMU 107. These waters will be released to the environment. This is not expected to pose a hazard to the public or the environment because of attenuation and dilution along the flowpath in the Valley Fill Alluvium. Therefore, this alternative minimizes future contaminant migration from the sources and minimizes future public exposure to contaminants off site.

4.3.3.3 Institutional Evaluation

ARARS pertinent to the total encapsulation alternative include the relevant and appropriate requirements under RCRA that address the technical specifications of capping closure and post-closure care, as well as requirements under RCRA pertaining to the storage of hazardous waste in waste piles, containers or tanks. In addition, soil that is excavated must be returned to the area from which it was originally removed to avoid triggering the restrictions on land disposal of solvent containing wastes.

Wastewater that is recovered from the source well within the encapsulated area must be treated in an on site or off site facility operating in compliance with RCRA. If recovered ground-water is to be treated on site in a treatment facility, specific RCRA requirements for the treatment of hazardous waste are relevant and appropriate. If wastewater is containerized and transported to the existing on site RCRA facility (existing treatment facility has interim status) the facility may need to modify its Part A to address the receipt of CERCLA wastes.

As mentioned, there may be concentrations of contaminants downgradient of the encapsulated areas that exceed RCRA Subpart F ground-water protection requirements. Therefore, there may be a period of time until contaminants are diluted and attenuated to sufficient levels where this remedial action does not comply with this relevant and appropriate provision of RCRA.

4.3.4 Source Well and Footing Drain

4.3.4.1 Technical Evaluation

Performance

Relative to the no action alternative, this alternative is expected to effectively improve the level of protection of public health and the environment. Although current conditions do not pose an imminent hazard to the public health, this alternative minimizes any future exposure of the public off site to the contaminants at the 881 Hillside.

The useful life of this alternative is expected to exceed thirty years. The footing drain at SWMU 107 has already been functioning satisfactorily for thirty years and there is no reason to believe that this will change. Well 9-74 has not been pumped routinely, but it is expected to be as efficient as any standard water well. The well is surrounded by monitoring wells so that an evaluation of the efficiency of the well can be easily made. Should the well prove abnormally inefficient, it will be replaced as part of routine maintenance for this alternative.

It appears likely that pumping of well 9-74 (or replacement) will be continuous for the first several years of remediation, but may not be required later. This is due to the small amount of ground water in the vicinity of SWMU 119.1. Collection of the footing drain flow will likely be required for the full thirty years.

Reliability

This system is expected to be highly reliable because the drain has been functioning for over thirty years without problems, and because wells have been used for collection of ground water for many years.

Operation and maintenance requirements for collection of the footing drain flow are minimal. Discharge from the drain will be collected in a double-lined surge tank and pumped to the treatment plant based on liquid level switches. Two pumps will be provided to protect against pump failure. In addition, the pumps will be connected to the plant emergency power so that the surge tank does not spill during a power failure.

Operation and maintenance of the dewatering well are similar. It too will be operated with a liquid level controller and requires little more than routine inspection.

Implementability

The system is highly implementable because the collection systems are already in-place, and the double-walled surge tank and associated mechanical connections are standard items. Well 9-74 has already been drilled and is of sufficient diameter to accept a standard submersible pump.

It is estimated that an operational system could be in place in approximately two weeks and that environmental improvement would begin immediately.

Safety

As with the other alternatives, a health and safety plan will be prepared for use in implementation of this alternative.

4.3.4.2 Environmental and Public Health Evaluation

Removal of the majority of contamination in the vicinity of well 9-74 will significantly minimize off-site migration of contaminants. Future off-site public exposure to the contaminants is unlikely; however, such exposure is more probable than that expected for alternatives that effectively contain and/or remove the contaminants.

4.3.4.3 Institutional Evaluation

Remedial actions at the 881 Hillside that involve the collection of contaminated ground water, treatment, and subsequent subsurface discharge must address two distinct sets of chemical, action, and location specific ARARs. First, alternative remedial actions considered for the remediation of the contaminated ground water are evaluated on their ability to attain applicable or relevant and appropriate cleanup concentrations or residual levels in the ground water after the remedial actions are completed. These ARARs are essentially performance goals of the ground-water remedial actions. In addition to the level of ground-water contaminant reduction achieved by the alternative, the alternatives should also address the time required to achieve the required remediation levels.

Ground Water Protection Standards (GWPS) under RCRA, 40 CFR Part 264, Subpart F, are identified as relevant and appropriate for ground-water remediation at the 881 Hillside. These rules act as the performance standard of the remedial action and are consistent with the remedial action goals of cleaning the ground water to levels that are background for organic compounds and at least achieve RCRA Maximum Concentration Limits (MCLs) for the metals parameters. For metals that do not have MCLs, the performance standard will be background levels. Related to the use of RCRA Ground Water Protection Standards as remedial action performance standards are the relevant and appropriate requirements of 40 CFR Section 264.100 that address corrective action monitoring. Corrective action monitoring is required to monitor the effectiveness of the corrective action and to ensure that GWPs are not exceeded beyond the compliance point. The selected remedial action alternative will include the implementation of a corrective action monitoring program.

Details of the chemical, action, and location specific ARARs associated with ground-water remediation are presented in the screening of ARARs found in Appendix 2.

<u>ARARs Associated with Ground-Water Treatment and Subsurface Discharge</u>

CHEMICAL-SPECIFIC ARARs

A distinct set of ARARs have been identified for remedial actions involving the subsurface discharge of treated ground water. Health-based chemical-specific ARARs pertinent to ground-water discharge have been identified and screened for the Hazardous Substance List organic and inorganic compounds found above detectable levels in the 881 Hillside wells. Radionuclides and conventional pollutants have also been identified and screened. Potential ARARs include applicable standards for the protection of ground water promulgated under the Colorado Water Quality Control Act, relevant and appropriate standards associated with the Clean WAter Act, and applicable standards defined by the Safe Drinking Water Act, Underground Injection Program.

Screening of the potential chemical-specific ARARs pertinent to subsurface discharge is documented in Appendix 2. A summary of the chemicals found to exceed ARARs as a result of this screening are presented in Table 4-6. An analysis of the chemical-specific ARARs identified for subsurface discharge reveals that the selected treatment alternative will provide treatment that exceeds ARARs for organic contaminants, but will not meet ARARs for certain metals (manganese and selenium) and gross alpha and gross beta.

One potential concern is that selenium levels in the treated effluent will be in concentrations that exceed CDH ground-water standards. These concerns may be unfounded based on investigations performed by the USGS on the distribution of selenium in ground water in the Golden, Colorado, area. Studies have shown areally discontinuous ground-water concentrations of selenium in the ground water in the vicinity of Golden. Thirty-four of fifty-six wells tested exceeded the SDWA MCL of 10 ug/l. Some wells contained as much as 450 ug/l selenium. Sources of the selenium are continental sedimentary rocks of the Arapahoe and Laramie Formations, of Cretaceous Age (Moran, 1976).

ACTION-SPECIFIC ARARs

Action-specific ARARs pertinent to subsurface discharge are the relevant and appropriate requirements of the Clean Water Act relating to substantive NPDES

TABLE 4-6

SUMMARY OF SCREENING CHEMICAL SPECIFIC ARARS
PERTINENT TO 881 HILLSIDE REMEDIAL ACTIONS

Chemicals Exceeding ARARS	Geometric Mean 881 Hillside Wells mg/l Alluvial	ARAR	Applicable, Relevant and Appropriate or To be Considered	Standard, Criteria or Guidance	Citation	Comment
Manganese	0.068 [0.547]	0.05	Applicable	ARAR is CDH human health ground water standard	5 CCR 1002-8, Section 3.11.5 dissolved concentration	CDH standard is applicable for subsurface discharge of treated groundwater.
Selenium	0.029 [0.005]	0.01	Applicable	ARAR is CDH human health ground water standard	5 CCR 1002-8, Section 3.11.5 dissolved concentration	CDH standard is applicable for subsurface discharge of treated groundwater.
Carbon Tetrachloride	8.40 ug/l	5 ug/l	R&A	ARAR is the SDWA MCL	40 CFR Part 141.50	Proposed CDH standards are not ARAR.
1,1 Dichloroethene	9.9 ug/l	7 ug/l	R&A	ARAR is the SDWA MCL	40 CFR Part 141.50	Proposed CDH standards are not ARAR.
Trichloroethene	22.0 ug/l	5 ug/l	R&A	ARAR is the SDWA MCL	40 CFR Part 141.50	Proposed CDH standards are not ARAR.
Gross Alpha	52.3 pCi/l [21.8]	15 pCi/l	R&A	ARAR is the CDH ground water	5 CCR 1002-8 Section 3.11.5	Note that the calculated geometric mean does not include the counting error associated with individual analyses and is therefore inaccurate.
Gross Beta	70.8 pCi/l [26.3]	50 pCi/l	R&A	ARAR is the SDWA MCL	40 CFR Part 141.26 (b)(1)(i)	The standard applies to public drinking water supplies but is R&A for ground water discharge. Note that the calculated geometric mean does not include the counting error associated with individual analyses and is therefore inaccurate.

TABLE 4-6
(continued)

SUMMARY OF SCREENING CHEMICAL SPECIFIC ARARS
PERTINENT TO 881 HILLSIDE REMEDIAL ACTIONS

Chemicals Exceeding ARARS	Geometric Mean 881 Hillside Wells mg/l Alluvial	ARAR	Applicable, Relevant and Appropriate or To be Considered	Standard, Criteria or Guidance	Citation	Comment
Total Dissolved Solids	1053 mg/l [161]	400 mg/l	R&A	ARAR is the CDH ground water quality standard	5 CCR 1002-8, Section 3.11.5(B)(4)	The identified ARAR applies directly to ground water quality

[ ] - Geometric mean concentration in background alluvial wells

- Background concentrations in alluvial wells exceed ARAR

requirements; relevant and appropriate requirements under RCRA for the storage and treatment of hazardous waste in containers and tanks; and applicable requirements under the Safe Drinking Water Act, Underground Injection Control Program.

The design, operation, and maintenance of the selected treatment facilities will meet chemical-specific ARARs identified for the contaminants of concern and action-specific ARARs related to the subsurface discharge of treatment system effluent. Highlights of these action-specific ARARs are listed below:

- o The use of best available technology (BAT) economically achievable is required to control toxic and non-conventional pollutants. Use of best conventional pollutant control technology (BCT) is required to control conventional pollutants.
- o Applicable federally approved state water quality standards must be complied with. These standards may be in addition to or more stringent than other federal standards under the Clean Water Act.
- o Develop and implement a Best Management Practices (BMP) program and incorporate into the NPDES permit to prevent the release of toxic constituents to surface waters. Note that on-site dischargers are exempt from procedural NPDES permit requirements.
- o General requirements for treatment and storage of RCRA hazardous waste in containers and tanks are relevant and appropriate. Recordkeeping requirements under these sections are not ARAR.
- o If a CERCLA response action at a Class IV injection well involves a RCRA listed waste that is subject to land disposal restrictions, the waste must be treated to Best Demonstrated Available Technology (BDAT) levels before reinjection.

LOCATION-SPECIFIC ARARs

Location-specific ARARs that are relevant and appropriate are the State of Colorado siting criteria for RCRA hazardous waste disposal sites found in the Colorado Hazardous Waste Act, Sections 25-15-101, 203, 208, and 302; and the Colorado Department of Health Water Quality Control Division's regulations pertaining to the need for WQCD approval of treatment facility location prior to construction.

4.4 ESTIMATED COSTS FOR ALTERNATIVES

Cost estimates were prepared using in-house computer software and unit rates. In-house unit rates are based upon Rocky Flats Plant experience in planning and managing similar construction projects at this site. Other recognized references were used where site specific unit rates were unavailable and for comparison or checking. These documents include: "Compendium of Remedial Technologies at Hazardous Waste Sites", U.S. EPA, September 1985; "Treatability Manual, Volume IV. Cost Estimating", U.S. EPA, April 1983; and "Building Construction Data", R.S. Means Co., Inc., 1987.

Costs are reported in 1988 dollars for both initial and future costs. Future costs include replacement of capital cost items (e.g., monitor wells or non-expendable items) and cyclic costs, such as operation and maintenance (O&M) costs, energy costs, and expendable supplies. Life cycle costs for each alternative have been presented, in 1988 dollars, as present worth costs assuming a discount rate of 10% and a duration of active remedy of thirty years.

Costs were analyzed by first identifying capital items common to one or more remedial alternatives. These capital items and associated costs are presented for each alternative in Table 4-7. Similarly, identified cyclic costs for each alternative are presented in Table 4-8. The two tables present the total capital cost and total operational and maintenance cost for each alternative.

Present worth analyses are performed by using the total costs presented in Tables 4-7 and 4-8. Present worth calculations are based on the assumptions that the duration of the remedy is 30 years, year "0" begins upon acceptance of a recommended remedy by the Lead Agency, the remedy becomes functional as year "1" begins, and activities continue through the end of year 30. Thirty years was selected as the expected duration of remedy for use in cost analyses for two principal reasons. 40 CFR 264.117 requires a minimum of 30 years post-closure monitoring and beyond 30 years costs become trivial. For example, at a discount rate of 10%, the discount factor (the ratio of the time value of 1988 dollars to the value of 2018 dollars) is 0.057. The required accuracy of these analyses is -30% to +50% of actual costs. Costs projected beyond 30 years will contribute less than 6% of their magnitude and thus become insignificant with respect to these analyses. These schedule assumptions are made to facilitate comparisons between alternatives and do not supersede any existing schedules created as a result of any administrative rule, statute, or agreement with agencies authorized to regulate remedial activities at this site. The present worth analysis (in 1988 dollars) is presented for each alternative in Tables 4-9 through 4-12.

Rigorous sensitivity analyses demonstrating the effect of possible variations or inaccuracies in assumptions or estimates have not been performed. Only one parameter, the duration of active remedial measures, was identified as being significant with respect to sensitivity analyses. By definition, the duration of the no action alternative must be at least 30 years (40 CFR 264.117) and is likely to be considerably longer. No action becomes financially less desirable, if because of enhanced effectiveness, other alternatives affect remedial goals in much less time. However, uncertainties in the rates of reclamation of the alternatives prevents performance of more rigorous analyses.

A discussion of cost benefits of individual alternatives is presented in Section 6, Summary of Alternatives. Estimated capital costs for the components used in assembly of alternatives are presented in Appendix 3.

Table 4-7 CAPITAL COSTS COMPONENT WORK SHEET

COMPONENT NUMBER	ALTERNATIVE NUMBER 1	3	5	7	Component Description
1	$49,260	$0	$0	$0	15 Monitoring Wells
5		$3,672		$3,672	1 ea Foundation Drain Sump w/ Pump
6		$1,219	$1,219	$1,219	1 ea Well Pump
7		$24,088			1160 LF Single Wall Pipe
9		$291,000		$291,000	1 ea Treatment Unit
10		$455,280			1640 LF French Drain
11		$7,400			1 ea French Drain Sump w/ Pump
12		$9,815			520 LF Single Wall Pipe, 1-1/2"PE
16			$143,472		58800 SF RCRA Cap
17			$138,600		19800 SF Slurry Wall
18			$32,000		1ea 7500 gal Tank Wagon
19			$4,282		Parking Pad
22				$3,721	4 ea Isolation Units
25		$51,756			Elec. Util. A3,4 & 8
26				$23,354	740 LF Double Contain Pipe, 1-1/2"PE
27			$25,878	$25,878	Elec. Util. A5 & A7
28				$16,411	410 LF Double Contain, 1-1/2"PE
29		$4,651			5 ea Isolation Units
SUB-TOTAL	$49,260	$848,881	$345,451	$365,255	
DESIGN @15	$7,389	$127,332	$51,818	$54,788	
CONSTR MGM	$2,463	$42,444	$17,273	$18,263	
CONTINGENC	$9,852	$169,776	$69,090	$73,051	
TOTAL CAPITAL COST	$68,964	$1,188,433	$483,631	$511,357	

Table 4-8 CYCLIC COSTS COMPONENT WORK SHEET
(Dollars per Year)

Ref No.	1	3	5	7	Component Description
1	$66,500	$66,500	$66,500	$66,500	15 Monitoring Wells
5		$200		$200	1 ea Foundation Drain Sump w/ Pump
6		$200	$200	$200	1 ea Well Pump
9		$68,000	$2,500	$68,000	1 ea Treatment Unit
18			$2,500		1ea 7500 gal Tank Wagon
29		$72,000		$72,000	Treatment System Monitoring (4 samples / Mo.)
SUB-TOTAL	$66,500	$206,900	$71,700	$206,900	
CONTIGENCY @20%	$13,300	$41,380	$14,340	$41,380	
TOTAL	$79,800	$248,280	$86,040	$248,280	

Table 4-9: PRESENT WORTH, REMEDIAL ALTERNATIVE 1, NO ACTION

YEAR	CAPITAL COSTS	O & M COSTS	TOTAL COSTS	DISCOUNT FACTOR 10.0%	PRESENT WORTH
0	$7,389	$79,800	$87,189	1.000	$87,189
1		$79,800	$79,800	0.909	$72,545
2		$79,800	$79,800	0.826	$65,950
3		$79,800	$79,800	0.751	$59,955
4		$79,800	$79,800	0.683	$54,504
5		$79,800	$79,800	0.621	$49,550
6		$79,800	$79,800	0.564	$45,045
7		$79,800	$79,800	0.513	$40,950
8		$79,800	$79,800	0.467	$37,227
9		$79,800	$79,800	0.424	$33,843
10	$61,575	$79,800	$141,375	0.386	$54,506
11		$79,800	$79,800	0.350	$27,969
12		$79,800	$79,800	0.319	$25,427
13		$79,800	$79,800	0.290	$23,115
14		$79,800	$79,800	0.263	$21,014
15		$79,800	$79,800	0.239	$19,103
16		$79,800	$79,800	0.218	$17,367
17		$79,800	$79,800	0.198	$15,788
18		$79,800	$79,800	0.180	$14,353
19		$79,800	$79,800	0.164	$13,048
20	$61,575	$79,800	$141,375	0.149	$21,014
21		$79,800	$79,800	0.135	$10,783
22		$79,800	$79,800	0.123	$9,803
23		$79,800	$79,800	0.112	$8,912
24		$79,800	$79,800	0.102	$8,102
25		$79,800	$79,800	0.092	$7,365
26		$79,800	$79,800	0.084	$6,696
27		$79,800	$79,800	0.076	$6,087
28		$79,800	$79,800	0.069	$5,534
29		$79,800	$79,800	0.063	$5,031
30		$79,800	$79,800	0.057	$4,573
	$130,539	$2,473,800	$2,604,339		$872,349

Table 4-10: PRESENT WORTH, REMEDIAL ALTERNATIVE 3, FR. DRAIN & TMT

YEAR	CAPITAL COSTS	O & M COSTS	TOTAL COSTS	DISCOUNT FACTOR 10.0%	PRESENT WORTH
0	$134,721	$79,800	$214,521	1.000	$214,521
1	$1,061,101	$248,280	$1,309,381	0.909	$1,190,347
2		$248,280	$248,280	0.826	$205,190
3		$248,280	$248,280	0.751	$186,536
4		$248,280	$248,280	0.683	$169,579
5		$248,280	$248,280	0.621	$154,162
6		$248,280	$248,280	0.564	$140,148
7		$248,280	$248,280	0.513	$127,407
8		$248,280	$248,280	0.467	$115,824
9		$248,280	$248,280	0.424	$105,295
10	$65,232	$248,280	$313,512	0.386	$120,872
11		$248,280	$248,280	0.350	$87,021
12		$248,280	$248,280	0.319	$79,110
13		$248,280	$248,280	0.290	$71,918
14		$248,280	$248,280	0.263	$65,380
15		$248,280	$248,280	0.239	$59,436
16		$248,280	$248,280	0.218	$54,033
17		$248,280	$248,280	0.198	$49,121
18		$248,280	$248,280	0.180	$44,655
19		$248,280	$248,280	0.164	$40,596
20	$65,232	$248,280	$313,512	0.149	$46,602
21		$248,280	$248,280	0.135	$33,550
22		$248,280	$248,280	0.123	$30,500
23		$248,280	$248,280	0.112	$27,727
24		$248,280	$248,280	0.102	$25,207
25		$248,280	$248,280	0.092	$22,915
26		$248,280	$248,280	0.084	$20,832
27		$248,280	$248,280	0.076	$18,938
28		$248,280	$248,280	0.069	$17,217
29		$248,280	$248,280	0.063	$15,651
30		$248,280	$248,280	0.057	$14,229
	$1,326,286	$7,528,200	$8,854,486		$3,554,519

Table 4-11: PRESENT WORTH, REMEDIAL ALTERNATIVE 5, ENCAPSULATION

YEAR	CAPITAL COSTS	O & M COSTS	TOTAL COSTS	DISCOUNT FACTOR 10.0%	PRESENT WORTH
0	$59,207	$79,800	$139,007	1.000	$139,007
1	$431,814	$86,040	$517,854	0.909	$470,776
2		$86,040	$86,040	0.826	$71,107
3		$86,040	$86,040	0.751	$64,643
4		$86,040	$86,040	0.683	$58,766
5		$86,040	$86,040	0.621	$53,424
6		$86,040	$86,040	0.564	$48,567
7		$86,040	$86,040	0.513	$44,152
8		$86,040	$86,040	0.467	$40,138
9		$86,040	$86,040	0.424	$36,489
10	$62,794	$86,040	$148,834	0.386	$57,382
11		$86,040	$86,040	0.350	$30,156
12		$86,040	$86,040	0.319	$27,415
13		$86,040	$86,040	0.290	$24,923
14		$86,040	$86,040	0.263	$22,657
15		$86,040	$86,040	0.239	$20,597
16		$86,040	$86,040	0.218	$18,725
17		$86,040	$86,040	0.198	$17,023
18		$86,040	$86,040	0.180	$15,475
19		$86,040	$86,040	0.164	$14,068
20	$62,794	$86,040	$148,834	0.149	$22,123
21		$86,040	$86,040	0.135	$11,627
22		$86,040	$86,040	0.123	$10,570
23		$86,040	$86,040	0.112	$9,609
24		$86,040	$86,040	0.102	$8,735
25		$86,040	$86,040	0.092	$7,941
26		$86,040	$86,040	0.084	$7,219
27		$86,040	$86,040	0.076	$6,563
28		$86,040	$86,040	0.069	$5,966
29		$86,040	$86,040	0.063	$5,424
30		$86,040	$86,040	0.057	$4,931
	========	========	========		===========
	$616,608	$2,661,000	$3,277,608		$1,376,200

Table 4-12: PRESENT WORTH, REMEDIAL ALTERNATIVE 7, TREAT EXISTING DISCHARGE

YEAR	CAPITAL COSTS	O & M COSTS	TOTAL COSTS	DISCOUNT FACTOR 10.0%	PRESENT WORTH
0	$62,177	$79,800	$141,977	1.000	$141,977
1	$456,569	$248,280	$704,849	0.909	$640,772
2		$248,280	$248,280	0.826	$205,190
3		$248,280	$248,280	0.751	$186,536
4		$248,280	$248,280	0.683	$169,579
5		$248,280	$248,280	0.621	$154,162
6		$248,280	$248,280	0.564	$140,148
7		$248,280	$248,280	0.513	$127,407
8		$248,280	$248,280	0.467	$115,824
9		$248,280	$248,280	0.424	$105,295
10	$64,013	$248,280	$312,293	0.386	$120,402
11		$248,280	$248,280	0.350	$87,021
12		$248,280	$248,280	0.319	$79,110
13		$248,280	$248,280	0.290	$71,918
14		$248,280	$248,280	0.263	$65,380
15		$248,280	$248,280	0.239	$59,436
16		$248,280	$248,280	0.218	$54,033
17		$248,280	$248,280	0.198	$49,121
18		$248,280	$248,280	0.180	$44,655
19		$248,280	$248,280	0.164	$40,596
20	$64,013	$248,280	$312,293	0.149	$46,420
21		$248,280	$248,280	0.135	$33,550
22		$248,280	$248,280	0.123	$30,500
23		$248,280	$248,280	0.112	$27,727
24		$248,280	$248,280	0.102	$25,207
25		$248,280	$248,280	0.092	$22,915
26		$248,280	$248,280	0.084	$20,832
27		$248,280	$248,280	0.076	$18,938
28		$248,280	$248,280	0.069	$17,217
29		$248,280	$248,280	0.063	$15,651
30		$248,280	$248,280	0.057	$14,229
	$646,772	$7,528,200	$8,174,972		$2,931,749

Table 4-13: SUMMARY OF ALTERNATIVE COSTS

ALTERNATIVE NUMBER	CAPITAL COSTS	YEAR INCURRED	ANNUAL COSTS	PRES WORTH COSTS
1	$7,389	0	$79,800	
	$0	1		
	$61,575	10		
	$61,575	20		
	$130,539	TOTAL		$872,349
3	$134,721	0	$248,280	
	$1,061,101	1		
	$65,232	10		
	$65,232	20		
	$1,326,286	TOTAL		$3,554,519
5	$59,207	0	$86,040	
	$431,814	1		
	$62,794	10		
	$62,794	20		
	$616,608	TOTAL		$1,376,200
7	$62,177	0	$248,280	
	$456,569	1		
	$0	10		
	$0	20		
	$518,746	TOTAL		$2,931,749

SECTION 5

SUMMARY OF ALTERNATIVES

5.1 INTRODUCTION

This section summarizes the retained alternatives and presents a tabular comparison of them. In addition to the four alternatives retained after the initial screening, a fifth alternative involving off-site disposal (eliminated in the screening process) is also presented in order to have an alternative in each of the five categories discussed in Section 3. After summarizing the alternatives and presenting the tabular comparison, a recommendation is made for appropriate remedial action.

5.2 COMPARISON OF ALTERNATIVES

Four alternatives were retained in the screening process and evaluated in detail. These are reviewed in this section together with an alternative involving off-site disposal. The alternatives considered in this section are:

1. No action;
2. French drain, collection of footing drain flow, pumping of source well at SWMU 119.1, and water treatment;
3. Total encapsulation;
4. Collection of footing drain flow, pumping of source well at SWMU 119.1, and water treatment; and
5. French drain, collection of footing drain flow, and water treatment coupled with soil excavation and off-site disposal.

These alternatives are discussed below and highlights of the detailed evaluations are presented in Table 5-1.

TABLE 5-1

SUMMARY OF ALTERNATIVES

Alternatives & Present Worth	Public Health & Environmental Environmental Concerns	Technical Concerns	Institutional Factors	Comments
1. No Action $872,000	Under no-action, contaminant releases will continue. However, current releases are diluted and/or attenuated to non-detectable levels at relatively short distances from the SWMUs. Extensive environmental monitoring is a part of the no-action alternative.	Modeling has shown that detectable concentrations should not reach the property boundary *for* at least 30 years after contaminants reach the Valley Fill Alluvium, assuming no attenuative mechanisms (volatilization and adsorption). In the 20 to 30 years that the SWMUs have been on the Hillside, contaminants have not reached the Valley Fill Alluvium because of the small quantity of ground-water flow.	Public opposition to the no-action alternative can be expected, although there is little present hazard to public health. Provision of long-term site security and monitoring is required.	Does not meet ground-water quality standards.
3. French Drain with Ground-water Treatment $3,555,000	The french drain will provide positive collection of all contaminated ground-water flow from the Hillside and will therefore prevent contaminant releases to the environment.	Long-term environmental monitoring is required.	Discharge from the treatment plant will probably require an amendment to the existing NPDES permit for discharges from Pond C-2.	Meets or exceeds ARARs.

TABLE 5-1
(CONTINUED)
SUMMARY OF ALTERNATIVES

Alternatives & Present Worth	Public Health & Environmental Environmental Concerns	Technical Concerns	Institutional Factors	Comments
5. Total Encapsulation $1,376,000	Encapsulation will contain all future releases from the SWMUs. A small quantity of ground water with low levels of VOCs will be allowed to flow toward Woman Creek. Should contaminants reach the Valley Fill Alluvium, they will be diluted to acceptable concentration at the property boundary.	The encapsulation system uses proven technology and is expected to perform well. Routine maintenance of the cover and ditches is required.	Long-term security and monitoring are required.	Meets ground-water quality standards with the exception of water immediately downgradient of SWMU 119.1 that will be released.
7. Source Well & Footing Drain $2,932,000	Pumping of a well at SWMU 119.1 and collection of footing drain flow, followed by treatment of the collected water, will result in immediate improvement of ground-water quality conditions at SWMU 119.1 and provide added protection against detectable releases to surface water from SWMU 107. Ground water containing low levels of VOCs downgradient of SWMU 119.1 will be released, but this is not considered to pose a hazard (see Alt. 3).	There is insufficient data to reliably conclude that there will not be public exposure to contaminants off-site at some point in the future.	Public opposition may be expected because of the limited scope of the response. Long-term monitoring is required.	Does not meet ARARs but will significantly minimize future hazards to the public health.

TABLE 5-1
(CONTINUED)
SUMMARY OF ALTERNATIVES

Alternatives & Present Worth	Public Health & Environmental Environmental Concerns	Technical Concerns	Institutional Factors	Comments
8. French Drain with Soil Removal & Off-site Disposal $3,360,000	The drain will provide positive collection of all ground-water flow from the Hillside and will therefore prevent contaminant releases to the environment. Removal of soils at SWMU 119.1 may shorten duration of remedial action but does not provide significantly improved environmental protection as the soils themselves are not hazardous.	The drain should be very reliable. Removal of soils from SWMU 119.1 is expected to reduce the required treatment time. Dust and contaminant volatilization could be generated by soil excavation.	Long-term environmental monitoring is required. Approximately 200 truck trips will be generated by the alternative, with consequent traffic hazard.	Meets or exceeds ARARs. Alternative eliminated in screening because of high cost with insignificant improvement, but presented here for completeness.

The no-action alternative will not meet ground-water quality standards but does not pose a substantial present imminent hazard to the public or the environment. Nevertheless, some public opposition can be expected to the no-action alternative.

The french drain coupled with ground-water treatment will meet ground-water quality standards and will halt releases to the environment.

Total encapsulation will prevent all future releases from the SWMUs but will allow a small quantity of ground water with low concentrations of volatile organics (in the range of 5 to 150 ug/l) to be released. The portion of this water that is not consumed by evapotranspiration will ultimately reach the Woman Creek Valley Fill Alluvium and flow east toward the property boundary. Calculations have been performed indicating that a constant 1,000 ug/l source will result in detectable volatile concentrations (5 ug/l) at the boundary in approximately 30 years. The release from the total encapsulation alternative is well below the assumed 1,000 ug/l source term and it will be of limited duration; therefore, it is unlikely that volatile organics will ever be detected at the boundary from this release. This alternative uses proven technology intended for much higher contamination levels than are present on the 881 Hillside; thus, public reception of the alternative should be good, except in so far as the public may be concerned about the small contaminant release to the Valley Fill Alluvium.

Collection of the footing drain flow and pumping of an existing well at SWMU 119.1 (with treatment of collected water) is a limited scope response that should make a significant impact on releases from the two SWMUs. Although volatiles currently are not detectable in the surface waters receiving flow from the footing drain, collection and treatment of the footing drain flow will provide an extra level of assurance that significant releases will not occur in the future. Pumping the well completed in the center of SWMU 119.1 will clearly improve conditions by removing the most contaminated ground water. Continued pumping may result in complete dewatering of the colluvial materials beneath the SWMU because of limited recharge to the area.

The french drain with ground-water treatment, coupled with removal and off-site disposal of the soils in the most contaminated area will undoubtedly be effective in minimizing releases of contaminants to the environment. Soil removal and off-site disposal may shorten the ground-water treatment time to the extent that volatile organics in the soils are the source of the volatiles in the ground water. Otherwise, volatile organic concentrations in the soil do not pose an unacceptable public health risk, and their removal and disposal as a RCRA hazardous waste is not cost effective.

5.3 RECOMMENDED REMEDIAL ACTION

It is recommended that the french drain with treatment of collected water alternative be implemented at the 881 Hillside. This alternative was selected using the following logic.

1. The no-action alternative does not meet the objectives of the feasibility study and is likely to receive public opposition.
2. The french drain with soil removal alternative is considerably more expensive than the other alternatives and does not provide greater protection of the public and the environment.
3. The total encapsulation alternative is by far the least expensive but requires long term management of the site and allows a contaminant release to the environment.
4. The footing drain/source well alternative does not result in appreciable cost savings relative to the french drain alternative because of the high cost of treating the water.

Therefore, the french drain with treatment of collected water alternative is recommended because it provides positive control of contaminated ground-water flow from the Hillside and treatment of collected water in a cost-effective manner.

SECTION 6

RECOMMENDED ALTERNATIVE

This alternative involves construction of a french (trench) drain to intercept all contaminated ground water from the 881 Hillside Area (see Figure 3-3). The downstream face of the trench will be covered with a synthetic membrane to limit flow from the clean side of the trench. The inclusion of the downstream synthetic membrane coupled with the continuity of the drain is expected to provide positive cutoff of the ground water. Water collected from the drain plus a source well at SWMU 119.1 (well 9-74) will be treated in a new treatment plant. In addition, a sump will be built to collect the flow from the Building 881 footing drain. Sump pumps will be used to move the footing drain flow to the treatment plant in a separate piping system. Effluent from the treatment plant will be conveyed downgradient of the french drain and reinnjected into the Valley Fill Alluvium of the Woman Creek drainage.

The conceptual design of this alternative involves a drain approximately 15 feet deep (in order to fully penetrate the soils) and 1,650 feet long. A drainage pipe (PVC) inside the drain will flow under gravity to a single central collection sump (3 foot diameter corrugated metal pipe). A submersible sump pump will be used to deliver the water from the drain to the treatment plant. In order to expedite contaminant removal from SWMU 119.1, well 9-74 will also be pumped and routed to the treatment plant in separate plumbing.

The ground water collected from the footing drain and french drain will be treated using a UV peroxide system. An existing heated building will be used as an enclosure for the water treatment system to protect weather or temperature sensitive components. External water pipes will be buried approximately four feet to protect against freezing. Major components of the treatment system include:

Exterior to Building

1. Two foam insulated 15,000-gallon influent surge tanks.
2. One foam insulated 15,000-gallon effluent tank.
3. Roughing filters.
4 Process water.
5 Associated pumps, gages, and valves.

Interior to Building

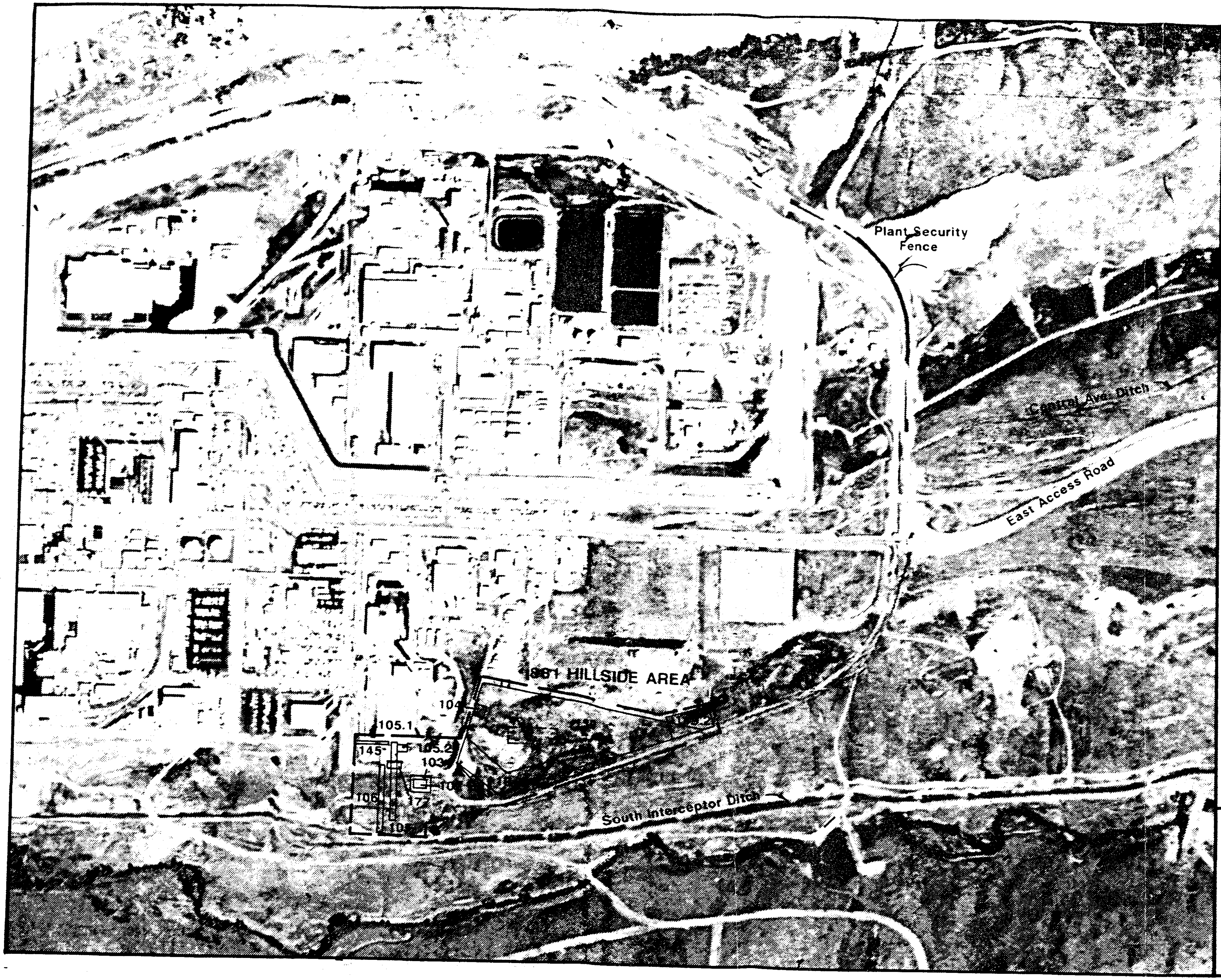
1. Selected treatment unit.
2. Parallel system of particulate filters
3. Sump pump.
4. Associated pumps, gages, and valves.
5. Support equipment for treatment unit.

Ground water and footing drain water will be pumped through roughing filters, to remove suspended solids, and then pumped into the surge tanks. The flows from the different sources are expected to be variable. The surge tanks will ensure a constant flow through the treatment unit at 30 gpm, in a batch process. These tanks will also provide approximately two days collection potential when the treatment unit is down for repairs, cleaning, etc.

When the treatment is initiated, the water will be pumped from the surge tanks through particulate filters to remove remaining suspended materials. The filters will be placed in descending order of size to remove progressively smaller particulates. The water will next enter the treatment unit.

The UV/peroxide treatment unit consists of an 80-gallon stainless steel oxidation chamber, which provides for a maximum ground-water retention time of 2.66 minutes at a constant system flowrate of 30 gpm. The oxidation chamber contains four medium pressure UV lamps, which are mounted horizontally in quartz sheaths. A hydrogen peroxide feed system is used to inject approximately 50 mg/l (per ppm of contaminants) of a 50 percent H_2O_2 solution into the ground-water feed line. The ground-water/peroxide mixture then passes through an in-line static mixer before entering the bottom of the oxidation chamber. The ground water then flows through the reaction chamber, passing the UV lamps, before it exits the top of the oxidation chamber. Flow through the oxidation chamber will be turbulent in nature to provide for the optimum degree of contaminant oxidation. As the ground water passes the UV lamps, the contaminants will be effectively destroyed to non-detectable levels.

Following treatment, the water will be directed to an effluent tank before reinjection. If contaminants continue to be present in ground water after several years of treatment, the soil flushing process described for Alternative 4 may be implemented to facilitated contaminant removal from the 881 Hillside. A portion of the treated effluent will be used to flush the soils.



- N -

EXPLANATION:

☐ Location of Solid Waste Management Unit

⌜⌟ Location of Areas of Interest Within Solid Waste Management Unit

101 Solid Waste Management Unit Reference Number (Rockwell International, 1986a)

NOTES:

1) Base map photo-enlarged from aerial photography of Rocky Flats Plant taken May 20, 1986.

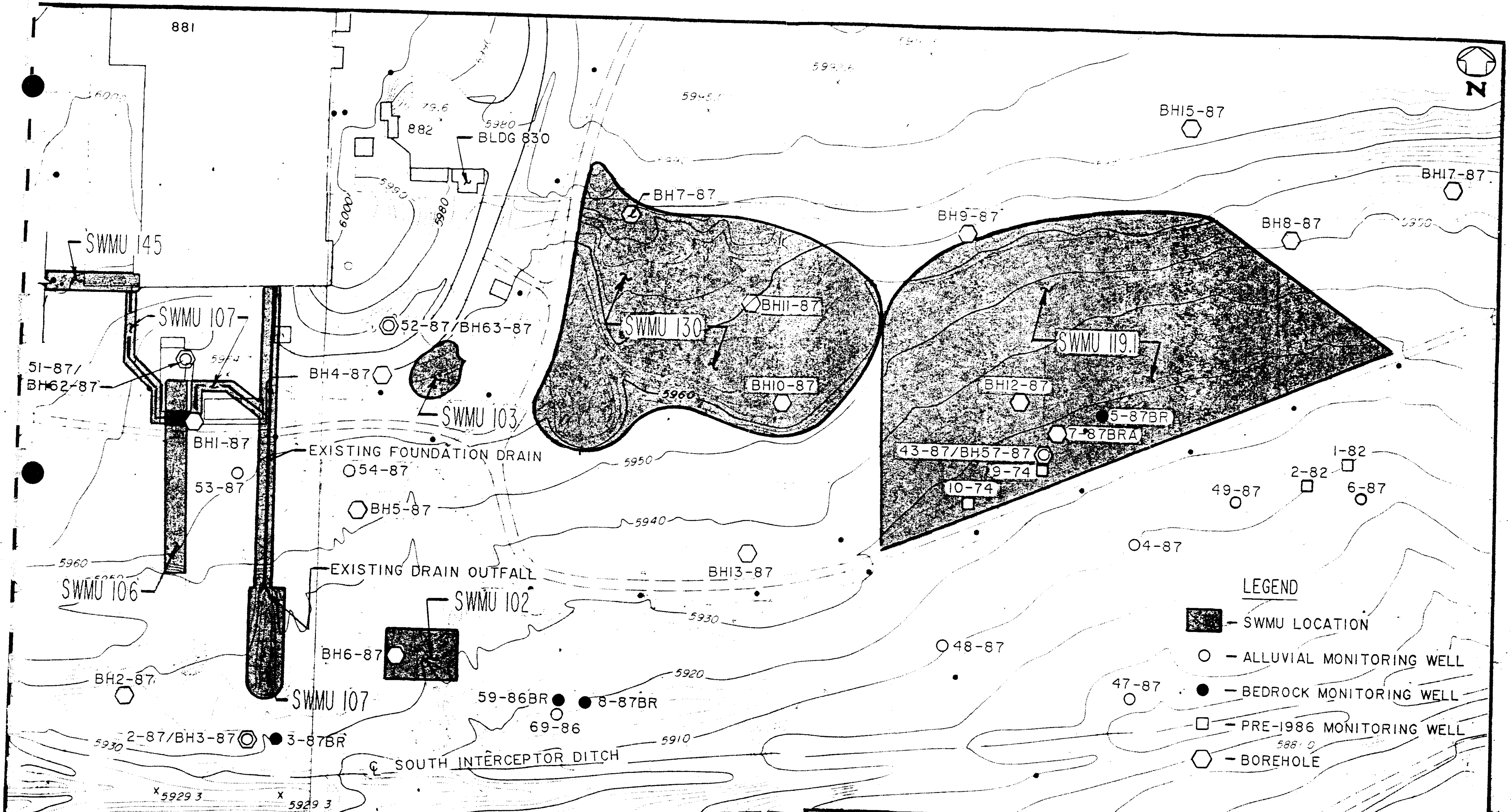
2) The locations of the solid waste management units have been located as accurately as possible, based on information available prior to 1987 remedial investigation.

1" = 500'

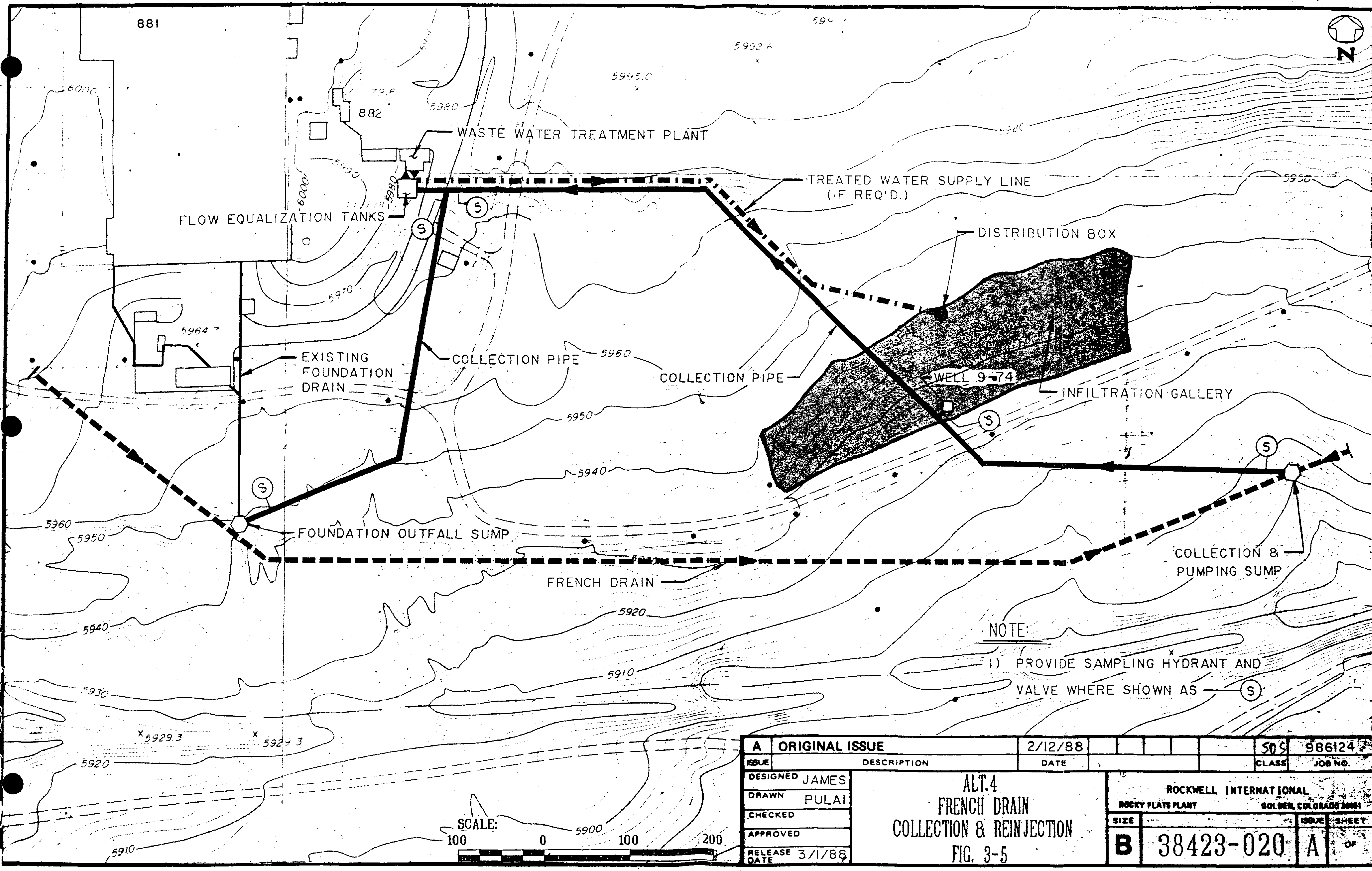
0 500' 1000'

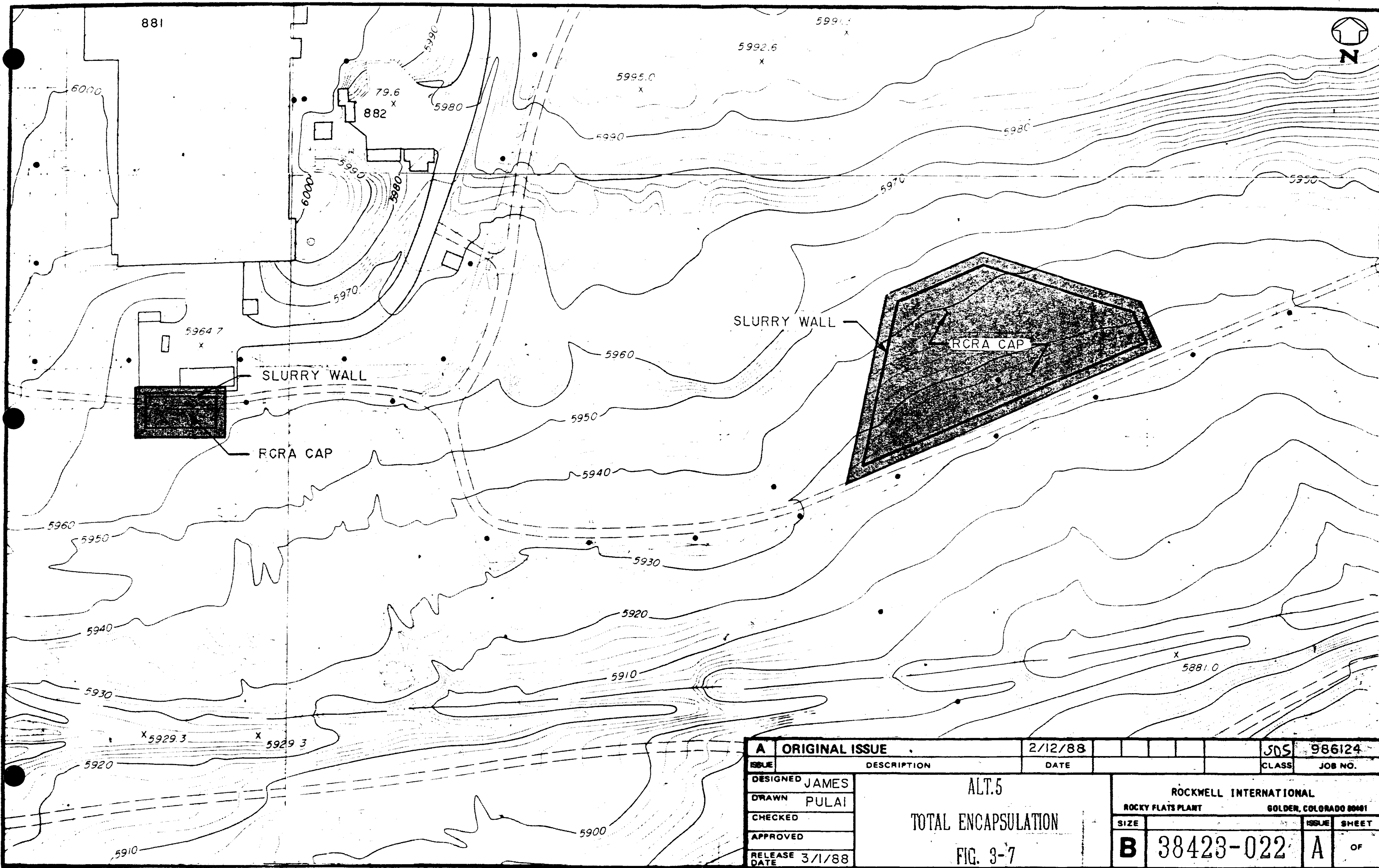
Figure 1-3: Remedial Investigation Area Locations and Associated Solid Waste Management Units

March 1, 1988



A	ORIGINAL ISSUE	2/12/88	SDS	986124
ISSUE	DESCRIPTION	DATE	CLASS	JOB NO.
DESIGNED JAMES	SITE FEATURE MAP	ROCKWELL INTERNATIONAL		
DRAWN PULAI		ROCKY FLATS PLANT GOLDEN, COLORADO 80401		
CHECKED		SIZE B	38423-015	ISSUE A
APPROVED		SHEET	OF	
RELEASE DATE 3/1/88	FIG. 3-1	BLDG.	ROOM	CAT.


881
882
N
WASTE WATER TREATMENT PLANT
FLOW EQUALIZATION TANKS
TREATED WATER SUPPLY LINE
(IF REQ'D.)
DISTRIBUTION BOX
EXISTING
FOUNDATION
DRAIN
COLLECTION PIPE
COLLECTION PIPE
WELL 9-74
INFILTRATION GALLERY
FOUNDATION OUTFALL SUMP
FRENCH DRAIN
COLLECTION &
PUMPING SUMP
NOTE:
1) PROVIDE SAMPLING HYDRANT AND
VALVE WHERE SHOWN AS (S)
6000
5980
5970
5964.7
5960
5950
5940
5930
5920
5910
5900
5995.0
5992.6
5929.3
5929.3
SCALE:
100
0
100
200
A
ORIGINAL ISSUE
2/12/88
ISSUE
DESCRIPTION
DATE
505
986124
CLASS
JOB NO.
BLDG
ROOM
CAT.
DESIGNED JAMES
DRAWN PULAI
CHECKED
APPROVED
RELEASE DATE 3/1/88
ALT. 4
FRENCH DRAIN
COLLECTION & REINJECTION
FIG. 3-5
ROCKWELL INTERNATIONAL
ROCKY FLATS PLANT
GOLDEN, COLORADO
SIZE
B
38423-020
ISSUE
A
SHEET
OF



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ISSUE	DESCRIPTION	DATE	CLASS	JOB NO.

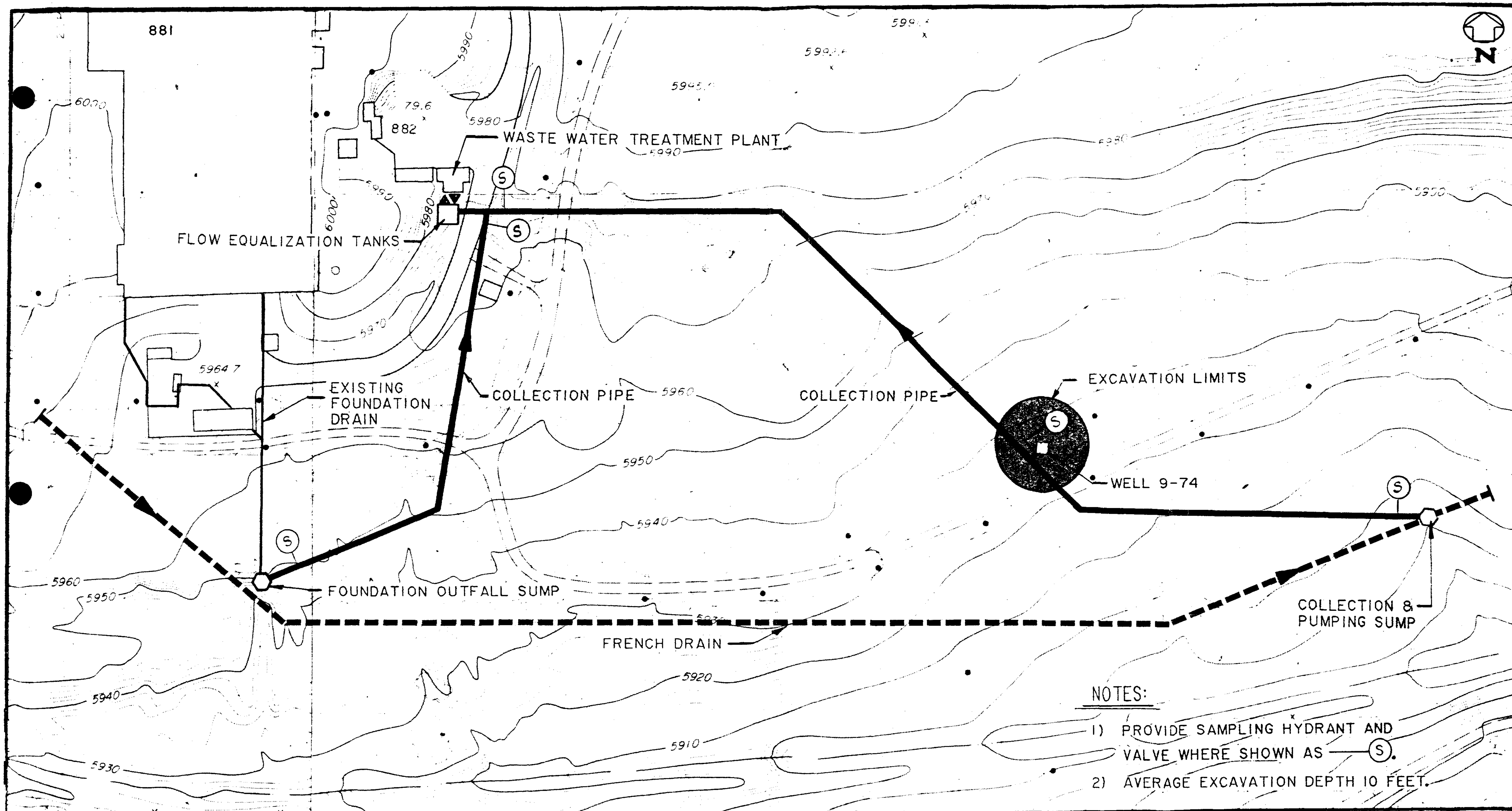
DESIGNED JAMES
DRAWN PULAI
CHECKED
APPROVED
RELEASE DATE 3/1/88

ALT.5
TOTAL ENCAPSULATION
FIG. 3-7

ROCKWELL INTERNATIONAL
ROCKY FLATS PLANT GOLDEN, COLORADO 80401

SIZE		ISSUE	SHEET
B	38423-022	A	OF

BLDG
ROOM
CAT.



NOTES:

1) PROVIDE SAMPLING HYDRANT AND VALVE WHERE SHOWN AS (S).

2) AVERAGE EXCAVATION DEPTH 10 FEET.

A	ORIGINAL ISSUE	2/12/88	
ISSUE	DESCRIPTION	DATE	
SDS	986124		
CLASS	JOB NO.	BLDG.	

DESIGNED JAMES
DRAWN PULAI
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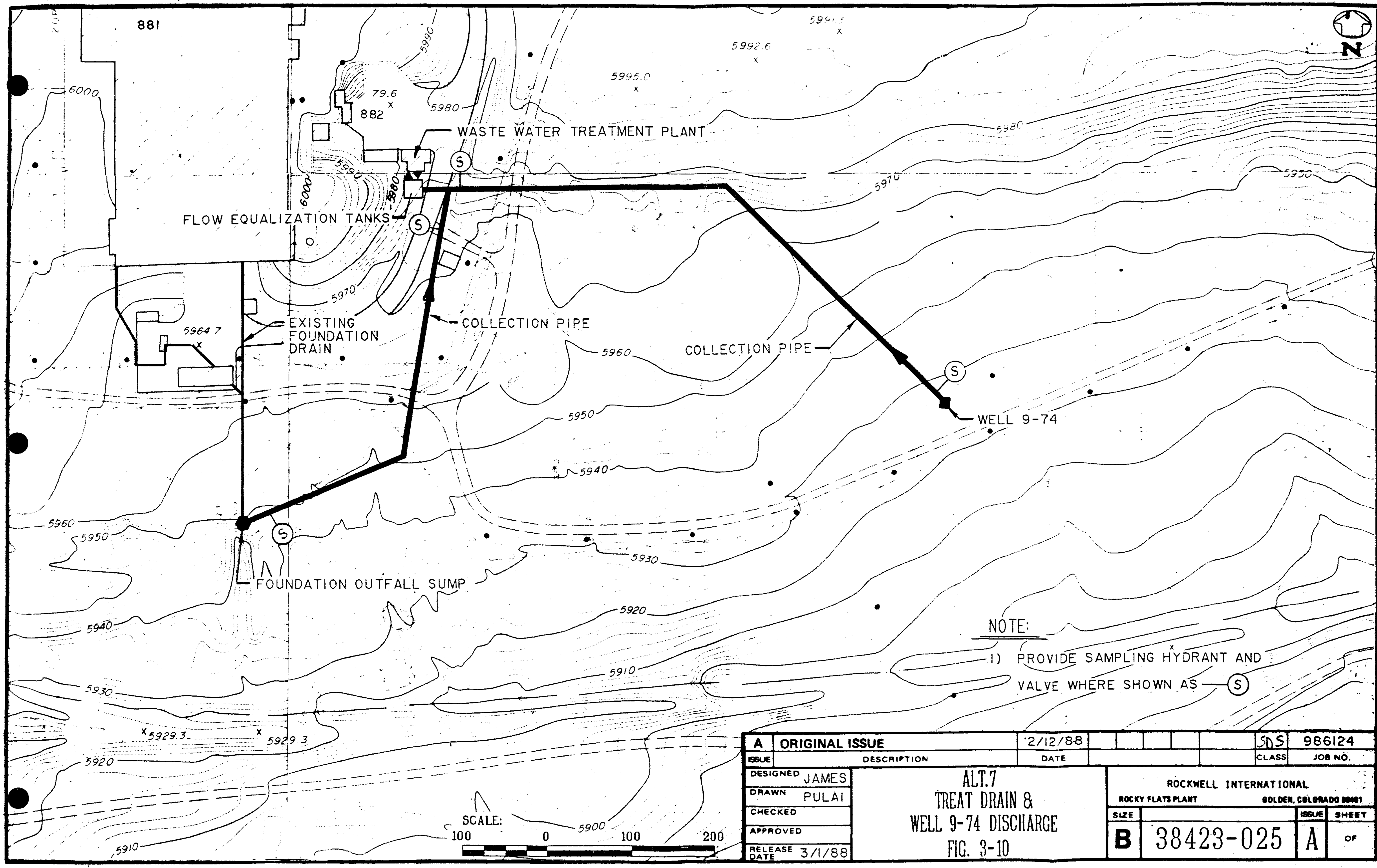
APPROVED
RELEASE DATE 3/1/88

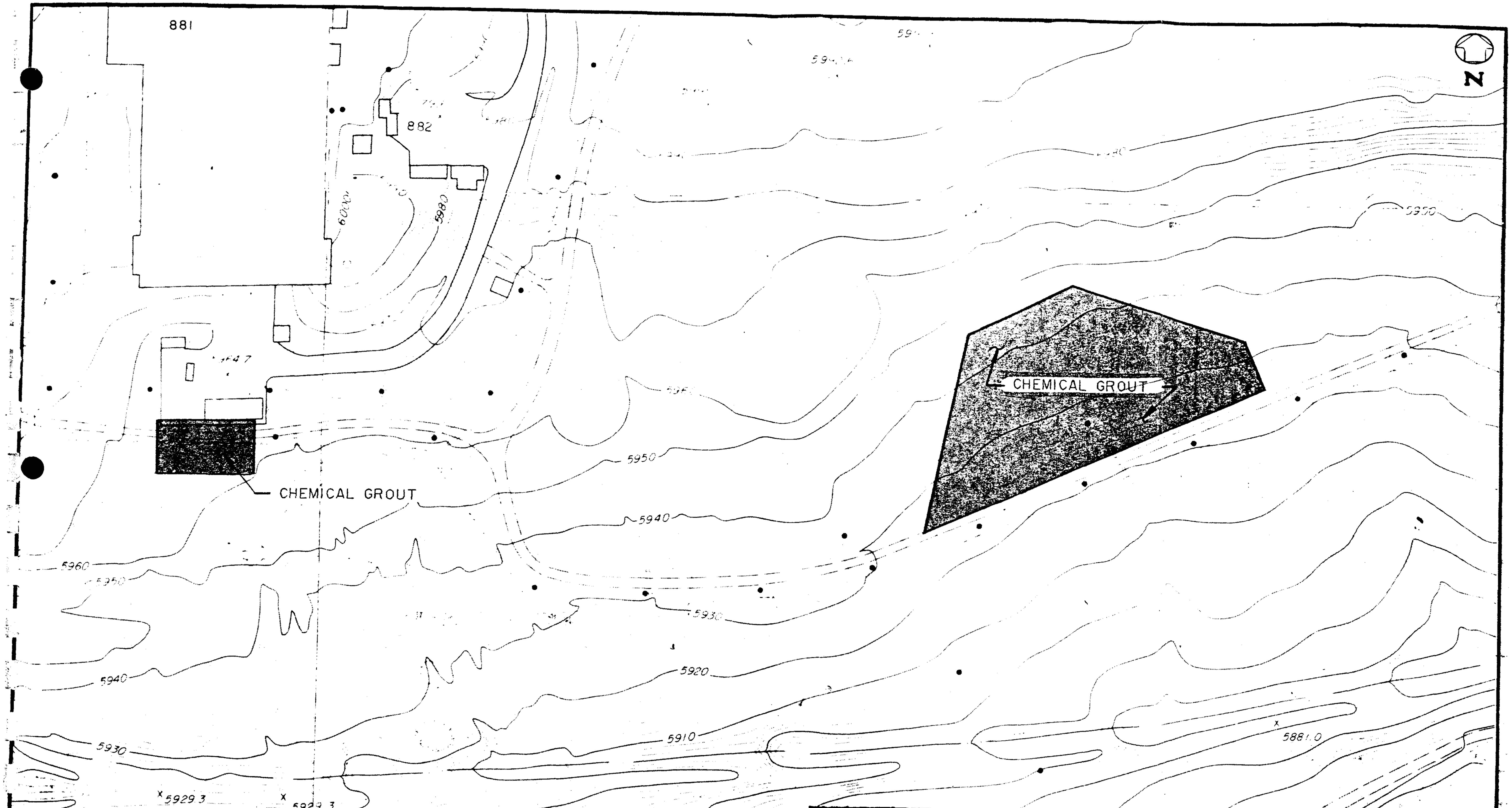
ALT.8
FRENCH DRAIN COLLECTION, TREATMENT & SOIL DISPOSAL
FIG. 3-11

ROCKWELL INTERNATIONAL
ROCKY FLATS PLANT GOLDEN, COLORADO 80401

ROOM
CAT.

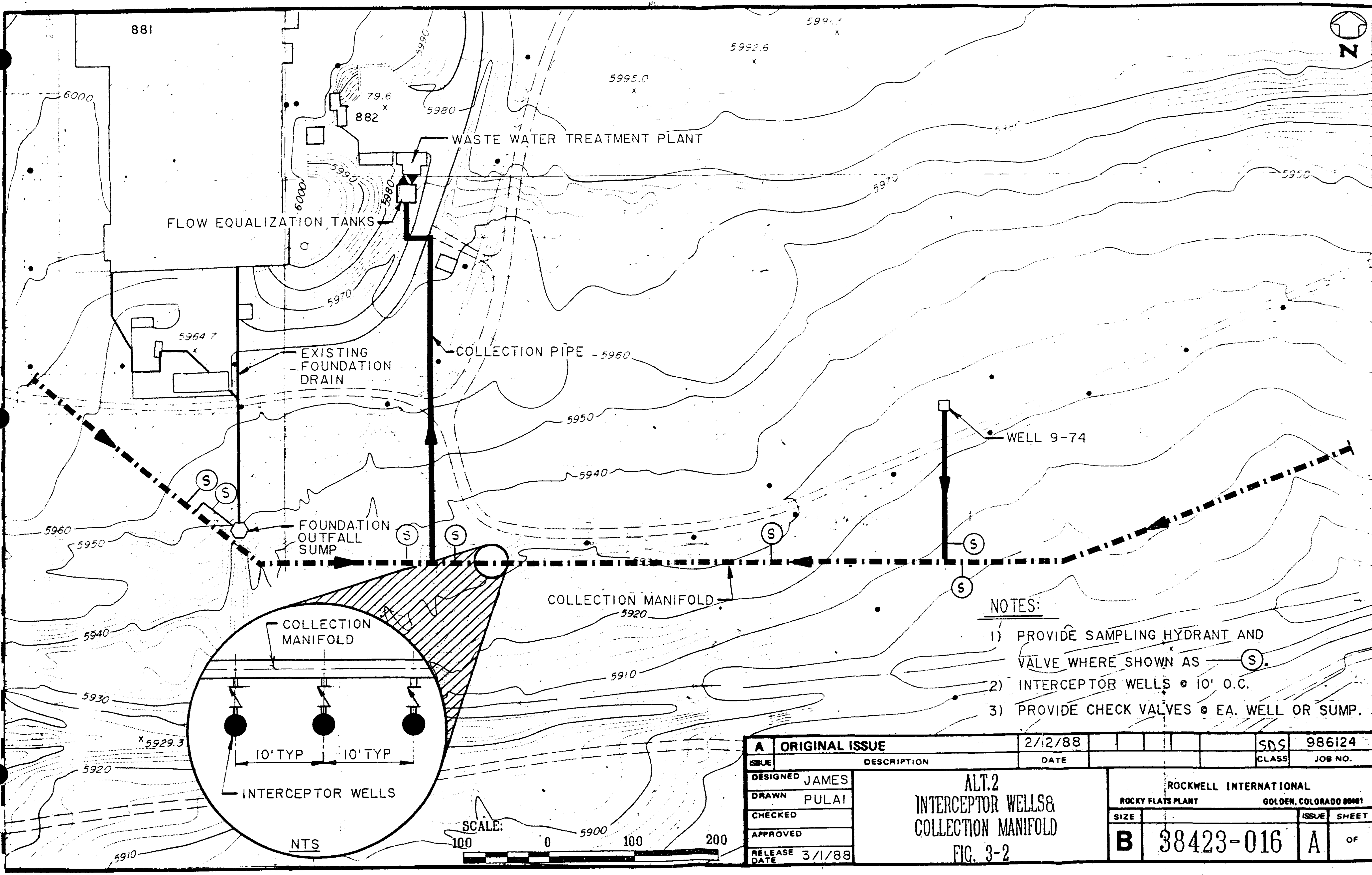
SIZE		ISSUE	SHEET
B	38423-026	A	7 OF


881
882
79.6
WASTE WATER TREATMENT PLANT
FLOW EQUALIZATION TANKS
EXISTING FOUNDATION DRAIN
COLLECTION PIPE
COLLECTION PIPE
WELL 9-74
FOUNDATION OUTFALL SUMP
5995.0
5992.6
5964.7
5929.3
5929.3
6000
5990
5980
5970
5960
5950
5940
5930
5920
5910
5900
NOTE:
1) PROVIDE SAMPLING HYDRANT AND VALVE WHERE SHOWN AS (S)
SCALE:
100
0
100
200
A
ORIGINAL ISSUE
2/12/88
ISSUE
DESCRIPTION
DATE
SDS
986124
CLASS
JOB NO.
BLDG
ROOM
CAT.
DESIGNED JAMES
DRAWN PULAI
CHECKED
APPROVED
RELEASE DATE 3/1/88
ALT.7
TREAT DRAIN &
WELL 9-74 DISCHARGE
FIG. 3-10
ROCKWELL INTERNATIONAL
ROCKY FLATS PLANT
GOLDEN, COLORADO
SIZE
B
38423-025
ISSUE
A
SHEET
OF



A	ORIGINAL ISSUE	2/12/88	SDS	986124
ISSUE	DESCRIPTION	DATE	CLASS	JOB NO.
DESIGNED JAMES	ALT.6	ROCKWELL INTERNATIONAL		
DRAWN PULAI	IMMOBILIZATION	ROCKY FLATS PLANT GOLDEN, COLORADO 80401		
CHECKED		SIZE	ISSUE	SHEET
APPROVED		B 38423-024	A	OF
RELEASE DATE 3/1/88	FIG. 3-9			

BLDG.
ROOM
CAT.



NOTES:

1) PROVIDE SAMPLING HYDRANT AND VALVE WHERE SHOWN AS —(S).
2) INTERCEPTOR WELLS @ 10' O.C.
3) PROVIDE CHECK VALVES @ EA. WELL OR SUMP.

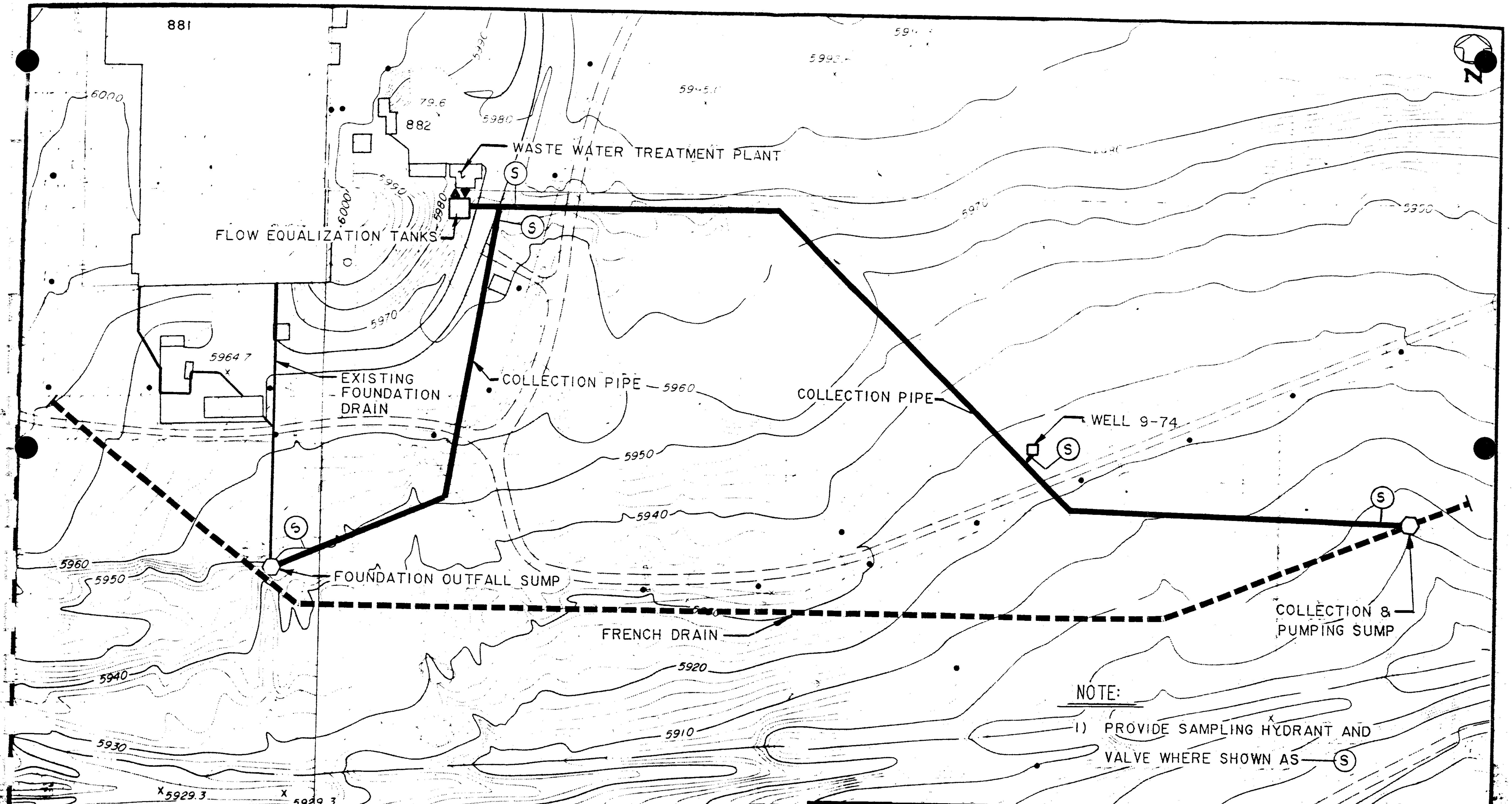
ISSUE	DESCRIPTION	DATE		CLASS	JOB NO.
A	ORIGINAL ISSUE	2/12/88		SDS	986124

DESIGNED	JAMES
DRAWN	PULAI
CHECKED	
APPROVED	
RELEASE DATE	3/1/88

ALT.2
INTERCEPTOR WELLS&
COLLECTION MANIFOLD
FIG. 3-2

ROCKWELL INTERNATIONAL
ROCKY FLATS PLANT GOLDEN, COLORADO 80401

SIZE		ISSUE	SHEET
B	38423-016	A	OF



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ISSUE	DESCRIPTION	DATE	CLASS JOB NO.

DESIGNED JAMES
DRAWN PULAI
CHECKED
APPROVED
RELEASE DATE 3/1/88

ALT.3
FRENCH DRAIN COLLECTION
FIG. 3-3

ROCKWELL INTERNATIONAL
ROCKY FLATS PLANT GOLDEN, COLORADO 80401

SIZE B 38423-018 ISSUE A SHEET OF

BLDG. ROOM CAT.